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Huntington, IN 46750

Plant Taxonomy

- Chairman.....JOE F. HENNEN, Department of Botany and
Plant Pathology
Purdue University, Lafayette, IN 47907
- Chairman-elect.....ORLAND J. BLANCHARD, Department of Biology
Earlham College, Richmond, IN 47374

Science Education

- Chairman.....LEON BERNHARDT, Department of Biology
Ball State University, Muncie IN 47306
- Chairman-elect.....HAROLD H. JAUS, Department of Education
Purdue University, Lafayette, IN 47907

Soil and Atmospheric Sciences

- Chairman.....FRANK W. SANDERS, Soil Conservation Service
5610 Crawfordsville Road, Indianapolis, IN 46224
- Chairman-elect.....HARRY M. GALLOWAY, Department of Agronomy
Purdue University, Lafayette, IN 47907

Zoology

- Chairman.....JOHN M. FERRIS, Department of Entomology
Purdue University, Lafayette, IN 47907
- Chairman-elect.....THOMAS JOSEPH, Department of Biology
Indiana University at South Bend, South Bend, IN 46615

ACADEMY FOUNDATION

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- FRANK A. GUTHRIE Rose Hulman Institute
(1975) 5500 Wabash Avenue
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BONDING COMMITTEE

- ROBERT M. BROOKER, Chairman Department of Chemistry
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- EARL A. HOLMES Department of Biology
(1975) St. Mary's College
Notre Dame, IN 46556

RESEARCH GRANTS COMMITTEE

- KENNETH E. NICHOLS, Chairman Valparaiso University
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- WINONA H. WELCH DePauw University
(1975) Greencastle, IN 46135

ROBERT M. BROOKER	Indiana Central College
(1977)	Indianapolis, IN 46227
CHARLES M. KIRKPATRICK	Department of Forestry and
(1978)	Conservation
	Purdue University
	Lafayette, IN 47907
DONALD R. BRANNON	Lilly Research Laboratories
(1979)	Eli Lilly and Company
	Indianapolis, IN 46206

EXECUTIVE COMMITTEE

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*BEHRENS, O. K.	*HAENISCH, E. L.	NICHOLS, K. E.
BENDA, R. S.	HENN, R. E.	OLSON, J. B.
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BROOKER, R. M.	*HOPP, W. B.	PATTON, J. B.
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CONKLIN, R. L.	KAUFMAN, K.	*POWELL, H. M.
COOK, D. J.	*LILLY, E.	SANDERS, F. W.
CORY, W. A., JR.	*LINDSEY, A. A.	*SCHMELZ, D. V.
CRANKSHAW, W. B.	MADSEN, D. C.	SCHWARTZ, E. P.
DAILY, F. K.	MAHLBERG, P.	SPOONER, J. A.
*DAILY, W. A.	*MARKLE, C. A.	ST. JOHN, P. A.
*DAY, H. G.	*MELLON, M. G.	VAN ATTA, R. E.
DHONAU, C. A.	METZ, C. R.	*WAYNE, W. J.
DINEEN, C. F.	*MEYER, A. H.	*WEATHERWAX, P.
*EDINGTON, W. E.	MEYER, R. W.	*WELCH, W. H.
FERRIS, J. M.	*MICHAUD, H. H.	WINSLOW, D. R.
*GIRTON, R. E.	*MORGAN, W. P.	*YOUSE, H. R.
*GUARD, A. T.	MOULTON, B.	

* Past President of Academy

BUDGET COMMITTEE

President—JOHN B. PATTON
 President-Elect—DONALD J. COOK
 Retiring President—DAMIAN V. SCHMELZ
 Secretary—ROBERT E. VAN ATTA
 Treasurer—CLYDE R. METZ
 Editor—BENJAMIN MOULTON
 Director of Public Relations—CLARENCE F. DINEEN
 Chairman, Library Committee—LOIS BURTON
 Co-Chairmen, Program Committee—DAVID W. OSGOOD, PHILIP A. ST. JOHN
 Director, Youth Academy—LAWRENCE POORMAN
 Chairman, Youth Activities—DONALD R. WINSLOW
 Chairman, Science and Society Committee—OTTO K. BEHRENS

COMMITTEES APPOINTED BY THE PRESIDENT

(The President and President-Elect are *ex officio* members of all committees.)

Academy Representative to A.A.A.S.**Section and Delegate to A.A.S.**

WILLIS H. JOHNSON (1974-77) Department of Biology
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Auditing Committee

C. A. DHONAU, Chairman Vincennes University
Vincennes, Indiana 47951
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R. E. DOLPHIN 1118 Chestnut Street
Vincennes, Indiana 47951

Youth Activities Committee

DONALD R. WINSLOW, Chairman . . Office of Research and Advanced
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KARL L. KAUFMAN, Coordinator of Science Fairs Butler University
Indianapolis, Indiana 46208

LAWRENCE POORMAN, Director of Junior Academy of Science Department of Physics
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Terre Haute, Indiana 47809

WALTER A. CORY, JR., Director of Indiana Science Talent Search . . School Science Coordinator's Office
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Bloomington, Indiana 47401

F. KEITH AULT Department of Chemistry
Ball State University
Muncie, Indiana 47306

JERRY M. COLGLAZIER Office of State Superintendent of
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120 West Market Street
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KEITH HUNNINGS New Haven High School
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JOHN C. MOODY	Division of Education Indiana University Southeast P. O. Box 679 New Albany, Indiana 47150
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Library Committee

LOIS BURTON, Chairman	Indiana State Library Indianapolis, Indiana 46204 Phone: 317-633-6425
NELLIE M. COATS	Indiana State Library Indianapolis, Indiana 46204
W. R. EBERLY	Department of Zoology Manchester College North Manchester, Indiana 46962
ELI LILLY	Eli Lilly and Company Indianapolis, Indiana 46206

Program Committee—Co-Chairmen

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PHILIP A. ST. JOHN	Department of Zoology Butler University Indianapolis, Indiana 46208 Phone: 317-283-9441

Publications Committee

MARION T. JACKSON, Chairman ...	Department of Life Sciences Indiana State University Terre Haute, Indiana 47809 Phone: 812-232-2489
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VIRGINIA R. FERRIS	Department of Entomology Purdue University Lafayette, Indiana 47907
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BENJAMIN MOULTON	Department of Geography and Geology Indiana State University Terre Haute, Indiana 47809
JOHN F. PELTON	Department of Botany Butler University Indianapolis, Indiana 46208

Membership Committee

DONALD J. COOK, Chairman	Department of Chemistry DePauw University Greencastle, Indiana 46135 Phone: 317-653-9721
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Corporation Membership:

OTTO K. BEHRENS, Ad Hoc Dir.	Eli Lilly and Company Indianapolis, Indiana 46206
KARL L. KAUFMAN	Butler University Indianapolis, Indiana 46208

Institutional Membership:

WILLIAM B. HOPP, Ad Hoc. Dir.	Indiana State University Terre Haute, Indiana 47809
FRANK A. GUTHRIE	Rose Hulman Institute Terre Haute, Indiana 47803

Emeritus Membership:

WINONA H. WELCH, Dir.	DePauw University Greencastle Indiana 46135
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Club Membership:

DONALD R. WINSLOW, Dir.	Indiana University Bloomington, Indiana 47401
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Fellows Committee**BENJAMIN MOULTON (1976)**

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JOHN A. RICKETTS (1976) Science Education
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CHARLES E. WIER (1976) Indiana Geological Survey
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RICHARD L. CONKLIN (1977) Department of Physics
 Hanover College
 Hanover, Indiana 47243

JAMES B. COPE (1977) J. Moore Museum
 Earlham College
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PAUL H. GEBHARD (1977) Institute for Sex Research
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 Bloomington, Indiana 47401

W. H. HEADLEE (1977) Department of Preventive Medicine
 I. U. Medical Center
 1100 West Michigan Street
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Resolutions Committee

- WILLIAM A. DAILY, Chairman . . . Eli Lilly and Company
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- JAMES E. NEWMAN Department of Agronomy
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Invitations Committee

- PHILIP A. ST. JOHN, Chairman . . Department of Zoology
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Phone: 317-283-9441
- PAUL R. QUINNEY Department of Chemistry
Butler University
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Necrologist

- FAY K. DAILY 5884 Compton Street
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Parliamentarian

- HOWARD K. YOUSE Department of Botany
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Science and Society Committee

- OTTO K. BEHRENS (1975)
Chairman Eli Lilly and Company
Indianapolis, Indiana 46206
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P. O. Box 263
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- GERALDINE M. HUITINK (1976) . . Department of Chemistry
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South Bend, Indiana 46615

- WILLIS H. JOHNSON (1976) Department of Biology
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- JERRY J. NISBET (1976) Office of University Evaluations
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- HARRY G. DAY (1977) Department of Chemistry
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- ROBERT E. HENDERSON (1977) Indianapolis Center for
Advanced Research
1300 West Michigan Street
Indianapolis, Indiana 46202
- RALPH A. LLEWELLYN (1977) Department of Physics
Indiana State University
Terre Haute, Indiana 47809

SPECIAL COMMITTEES APPOINTED BY THE PRESIDENT

Biological Survey Committee

- JACK R. MUNSEE, Chairman Department of Life Sciences
Indiana State University
Terre Haute, Indiana 47809
Phone: 812-232-2393
- GAYTON C. MARKS Valparaiso University
Valparaiso, Indiana 46383
- RUSSELL E. MUMFORD Department of Forestry and
Conservation
Purdue University
Lafayette, Indiana 47907
- JOHNNY W. REISING Indiana State University—
Evansville
1413 Ewing Street
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- WINONA H. WELCH DePauw University
Greencastle, Indiana 46135
- WILLARD F. YATES Department of Botany
Butler University
Indianapolis, Indiana 46208
- FRANK N. YOUNG, JR. Department of Zoology
Indiana University
Bloomington, Indiana 47401

Emeritus Member Selection Committee

- WINONA H. WELCH, Chairman ... DePauw University
Greencastle, Indiana 46135
Phone: 317-653-9721

ROBERT H. COOPER	R. R. 9—Box 242 Muncie, Indiana 47302
EDWARD L. HAENISCH	Department of Chemistry Wabash College Crawfordsville, Indiana 47933
HOWARD H. MICHAUD	301 East Stadium Drive Lafayette, Indiana 47906

Newsletter

CLARENCE F. DINEEN	Department of Biology St. Mary's College Notre Dame, Indiana 46556 Phone: 219-284-4061
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Preservation of Natural Areas Committee

WILLIAM B. BARNES, Chairman ..	Department of Natural Resources 616 State Office Building Indianapolis, Indiana 46204 Phone: 317-633-4164
MARION T. JACKSON	Department of Life Sciences Indiana State University Terre Haute, Indiana 47809
CARL H. KREKELER	360 McIntyre Court Valparaiso, Indiana 46383
DAVID W. OSGOOD	Department of Zoology Butler University Indianapolis, Indiana 46208
GEORGE R. PARKER	Department of Forestry and Conservation Purdue University Lafayette, Indiana 47907
ROBERT O. PETTY	Department of Biology Wabash College Crawfordsville, Indiana 47933
RICHARD L. POWELL	Indiana Geological Survey 611 North Walnut Grove Bloomington, Indiana 47401
DAMIAN V. SCHMELZ	Department of Biology St. Meinrad College St. Meinrad, Indiana 47577
ROBERT C. WEBER	3649 Algonquin Pass Fort Wayne, Indiana 46809
J. DAN WEBSTER	Department of Zoology Hanover College Hanover, Indiana 47243
WINONA H. WELCH	DePauw University Greencastle, Indiana 46135
CARROLLE MARKLE (Honorary) ..	Ashfield, Massachusetts 01330

"Speaker of the Year" Selection Committee

- HARRY G. DAY (1975), Chairman Department of Chemistry
Indiana University
Bloomington, Indiana 47401
- ALTON A. LINDSEY (1975) Department of Biological Sciences
Purdue University
Lafayette, Indiana 47907
- DAMIAN V. SCHMELZ (1975) Department of Biology
St. Meinrad College
St. Meinrad, Indiana 47577
- FRANK A. GUTHRIE (1976) Department of Chemistry
Rose Hulman Institute
Terre Haute, Indiana 47803

**Academy Representative on Indiana Natural Resources Commission
(Alternates)**

- DAVID W. OSGOOD Department of Zoology
Butler University
Indianapolis, Indiana 46208
Phone: 317-283-9411
- DAMIAN V. SCHMELZ Department of Biology
St. Meinrad College
St. Meinrad, Indiana 47577
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SPRING MEETING

MINUTES OF THE EXECUTIVE COMMITTEE MEETING

April 25, 1975

BROWN COUNTY STATE PARK, Brown County, Indiana

The meeting was called to order by President John Patton at 4:15 PM in the ground floor meeting room of Abe Martin Lodge in Brown County State Park. The minutes of the Executive Committee and of the General Session of the Fall, 1974 meeting were approved.

TREASURER'S REPORT

Treasurer Clyde Metz presented a financial report for the period January 1 through April 17, 1975. The following is the summary from his report:

	Academy Accounts	Administered Accounts	Total
Balance: January 1, 1975 -----	\$9,353.25	\$16,000.92	\$25,354.17
1975 Income -----	5,255.86	13,235.39	18,491.25
1975 Expenditures -----	8,031.36	13,184.23	21,215.59
Balance: April 17, 1975 -----	6,577.75	16,052.08	22,629.83

The Treasurer also reported that approximately one-half of the 1975 membership dues have been paid, and that the Academy funds available for the current year have been committed. The Treasurer's report was accepted by general consent.

STANDING COMMITTEE REPORTS

Academy Foundation Committee: William Daily, Chairman, reported that the John S. Wright Invested Income Account held \$11,000 as of April 18, 1975 and that the market values of the Foundation Account and the John S. Wright Fund have increased by more than 20% in the past six months.

Research Grants Committee: Kenneth Nichols, Chairman, reported that \$3153 has been granted for eight individual research projects this year.

Representative to Association of Academies of Science (AAS): Willis Johnson, Delegate, reported on his participation with representatives from the Utah, Iowa, and Florida academies in a panel discussion on academy scientific communications during the January meeting of the AAS. He also reported on the meeting of Section X, whose principal function is sponsoring symposia at AAAS meetings, and on suggested symposia for the 1976 AAAS meeting.

Program Committee: Philip St. John, Co-Chairman, reported that sites selected for future Fall meetings are as follows:

1975 Butler University
1976 Valparaiso University

1977 Indiana University-Purdue University-Indianapolis
1978 Anderson College

Publications Committee: William Eberly reported that "Natural Features of Indiana" will not be printed this year, due to low sales prospects and excessive costs, according to the Indiana University Press, which returned unsigned contracts. It was suggested that other avenues for future publication be explored. A manuscript for *Monograph IV* is under consideration.

Membership Committee: Donald J. Cook, Chairman, presented and explained the contents of the new membership application blank. The concept of expanded honorary membership as a means of improving Academy public relations was discussed.

Science and Society Committee: Otto Behrens, Chairman, reported on the current status of HB 1616, a bill to authorize formation of a state Council on Science and Technology. The bill was passed by the House, but died in the Senate Finance Committee. Current activities related to the Speakers' Bureau were described; further information will appear in the next Newsletter.

SPECIAL COMMITTEE REPORTS

Emeritus Member Selection Committee: Howard Youse, reporting for Winona Welch, Chairwoman, presented the following persons for Emeritus Membership (initial membership year shown in parentheses):

FERNANDUS PAYNE, Frankfort, Indiana (1913)
DAVID H. DUNHAM, West Lafayette, Indiana (1920)
SAMUEL W. WITMER, Goshen, Indiana (1921)
C. MERVIN PALMER, Kennett Square, Pennsylvania (1925)
NATHAN W. SHOCK, Baltimore, Maryland (1927)
WALLACE B. MINER, DeKalb, Illinois (1928)
THEODORE M. SPERRY, Pittsburg, Kansas (1928)
HERBERT M. CLARKE, Middleton, Wisconsin (1929)
DONALD C. HAZLETT, Russellville, Indiana (1930)
MARION M. FIDLAR, Salt Lake City, Utah (1931)
THEODORE W. TORREY, Bloomington, Indiana (1935)
PAUL BENDER, Goshen, Indiana (1936)
ROBERT F. DUNCAN, Shreveport, Louisiana (1938)
TRACY M. SONNEBORN, Bloomington, Indiana (1940)
PHILIP PEAK, Bloomington, Indiana (1945)
HELMUT M. KOHNKE, West Lafayette, Indiana (1946)
THOMAS F. BARTON, Bloomington, Indiana (1947)
S. J. SMUCKER, Rensselaer, Indiana (1947)
MARY ROSE STOCKTON, Indianapolis, Indiana (1948)

Motion: That the persons presented be elected to Emeritus Membership. Seconded and carried.

Preservation of Natural Areas Committee: William Barnes, Chairman, reported that three additional state nature preserves have been dedicated by action of the Natural Resources Commission; these include 6,094 acres or 34 percent of the total 177 recognized natural

areas in the state. The National Park Service has now designated 22 Registered Natural Landmarks in Indiana. It was suggested that formal dedication ceremonies for registered natural landmarks would be an appropriate Bicentennial Celebration activity for the Academy. The need for protection of endangered *plant* species was discussed in connection with the Endangered Species Act of 1973.

Motion: That an appropriate committee of the Academy be appointed to prepare a state list of endangered and threatened plant species. Seconded and carried.

"Speaker of the Year" Selection Committee: Damian Schmelz, reporting for Harry Day, Chairman, announced that Dr. Harold Cassidy of Hanover College has been selected speaker of the year for 1975-76. The five campuses on which he will speak during the next few months have not yet been selected; he will be the featured speaker at the 1975 Fall meeting.

Motion: That all Standing and Special Committee reports be accepted. Seconded and carried.

NEW BUSINESS

Motion: That the Executive Committee grant Honorary Membership status to Dr. Eli Lilly, 55-year member and former President of the Academy, in recognition of his lifelong interest in and contributions to science and the Indiana Academy.

Seconded and carried. Damian Schmelz will draw up a formal letter informing Dr. Lilly of this action.

Motion from the Membership Committee: That the Academy establish a tradition of appointing the Governor of the State as an Honorary Member at the Fall meeting immediately following his election and that Governor Bowen be so designated by the President of the Academy at the Fall 1975 meeting.

Seconded. Considerable discussion followed.

Substitute Motion: That the matter of Honorary Membership for the Governor of the State be referred back to the Membership Committee for further consideration and possible recommendation to be brought back to the Academy at the Fall 1975 meeting. Seconded and carried.

President Patton suggested that constitutional amendments with regard to Standing Committees previously approved by the Executive Committee be brought, in appropriate form, to the Fall 1975 meeting. This suggestion was accepted by general consent.

President Patton called attention to the fact that portions of the existing By-Laws require amendment to bring them into agreement with current practice with regard to members eligible to receive copies of *Proceedings*.

Motion: That *By-Laws, Article I. Dues, Sections 6 and 7* be changed to read as follows (changes in italics):

Sec. 6. Each Senior, Sustaining, Life, Emeritus, Honorary, Corporate, and Institutional member is entitled to one copy of the Proceedings of the Academy, etc.

Sec. 7. Former Senior or Sustaining members who were dropped for non-payment of dues may obtain one copy of the Proceedings, etc.

Seconded and carried.

President Patton referred to a letter from Theodore Crovello to William Barnes suggesting the establishment of an "Active State Flora" project similar to those of Colorado and British Columbia as a Bicentennial project. It was suggested that the Academy support a "Flora Indiana" project to be funded by support from various organizations. Referral of this matter to the Biological Survey Committee was approved by general consent.

President Patton presented a suggestion from Clyde Metz that Emeritus members' dues cards (marked no dues required) provide information on the current status of these members and should be returned to the Treasurer.

Damian Schmelz discussed the status of the Family Membership, which is not defined in the Academy Constitution and By-Laws. It was indicated that this type of membership exists by executive decision. Continuation of the Family Membership in this fashion was accepted by general consent.

David Osgood presented a discussion on the question of whether or not the Academy should take a position on a U. S. Corps of Engineers proposal to build a reservoir on Big Pine Creek near Lafayette. After some discussion, it was determined that appropriate procedure would be for information on the matter to be presented to the Resolutions Committee for formulation of a resolution to be presented to the General Session meeting.

Lois Burton reported on the status of current Academy appropriations requests in the state legislature.

The meeting was adjourned at 6:00 PM.

Respectfully submitted,
ROBERT E. VAN ATTA, Secretary

SPRING MEETING

MINUTES OF THE GENERAL SESSION

BROWN COUNTY STATE PARK, Brown County, Indiana

April 25, 1975

The meeting was called to order by President John Patton at 7:45 PM in the ground floor meeting room of Abe Martin Lodge in Brown County State Park.

Philip St. John, program co-chairman, introduced the speaker of the evening, Mr. Richard A. Davis, Head Librarian of Butler University.

A brief business meeting followed Mr. Wilson's address.

William Daily, Chairman, moved the adoption of the following resolutions on behalf of the Resolutions Committee:

1. That the Academy members here assembled express their appreciation to Mr. Phil Bessire, Lodge Manager; Tom Fulton, Park Superintendent; Mr. D. L. Herbst, Director, Division of Natural Resources, and their personnel for their hospitality and kind services. We are particularly grateful to Professors Philip St. John and David Osgood of Butler University, Co-chairmen of the Program Committee, for their fine work in the preparation of the program.

Our appreciation is extended to the leaders of the hikes, Drs. Russell Mumford, Austin Fergusson and Mr. Carl Rexroad.

We also wish to thank Mr. Richard A. Davis for a very informative lecture concerning Alexander Wilson, Pioneer and Prophet.

The resolution was approved.

2. WHEREAS: Several unresolved questions exist regarding the U. S. Corps of Engineers' reservoir project on Big Pine Creek, therefore

The Indiana Academy of Science hereby resolved that no funds be expended for land acquisition prior to the Indiana General Assembly making a new study of the benefits to be gained and the costs to be incurred in this project.

The resolution was approved.

David Osgood presented instructions regarding the Saturday morning programs. President Patton announced that there would be a brief meeting of all Divisional Chairmen and Chairmen-Elect immediately following the business meeting.

The meeting was adjourned at 9:00 PM.

Respectfully submitted,
ROBERT E. VAN ATTA, Secretary

FALL MEETING

MINUTES OF THE EXECUTIVE COMMITTEE MEETING

October 30, 1975

The meeting was called to order by President John B. Patton at 7:40 p. m. in Room 108 of Gallahue Science Hall at Butler University, Indianapolis, Indiana. The minutes of the Executive Committee Meeting and of the General Session for Spring 1975 were approved.

TREASURER'S REPORT

Treasurer Clyde R. Metz presented a financial report for the period January 1, 1975 through October 27, 1975, summarized as follows:

		Administered Accounts	Total
Balance: January 1, 1975 -----	\$9,353.25	\$16,000.92	\$25,354.17
1975 Income -----	9,044.69	17,755.39	26,800.08
1975 Expenditures -----	9,632.94	19,113.77	28,746.71
Balance: October 27, 1975 -----	8,765.00	14,642.54	23,407.54

The Treasurer also reported that 1975 income is less than expected due to the smaller than anticipated number of members electing the Senior membership category. The Treasurer's report was accepted.

COMMITTEE REPORTS

Program Committee. Philip A. St. John, Co-chairman, presented information pertaining to operations during the current meeting and called attention to the fact that abstracts of papers submitted late were available.

Academy Foundation Committee. William A. Daily, Chairman, presented a brief history of the initiation and development of the Academy Research Endowment Fund, followed by a complete survey of the present Academy portfolio, a summary of which follows:

Market Value of Original Foundation Fund:\$ 16,986.00
Total Income of John S. Wright Fund to
September 30, 1975: 16,525.07
Disbursements from John S. Wright Fund: 19,674.54
Balance in Invested Income: 12,000.00
Market Value of all Securities:\$505,192.00

Bonding Committee. No report.

Research Grants Committee. Kenneth E. Nichols, Chairman, reported that 12 research grants totaling \$4,650 have been awarded.

Representative on AAAS Council. Willis H. Johnson announced that the 1976 meeting of Section X will convene in Boston February 18-24, 1976.

Auditing Committee. Clyde R. Metz, reporting for Chairman C. A. Dhonau, stated that the books for 1974 have been approved and that the committee report will be published in *Proceedings*.

Youth Activities Committee. Walter A. Cory, reporting for Chairman Donald R. Winslow, presented a status report on the activities of the three youth activity programs sponsored by the Academy: the Science Fair program, the Science Talent Search, and the Indiana Junior Academy of Science.

The number of participants in the Science Fair Program has increased to more than 4000 from a thousand schools in this year's 12 regional fairs. Twenty-six of the 396 finalists at the International Science and Engineering Fair in Oklahoma City were from Indiana, winning seven major awards and several special health awards.

The 28th Annual Indiana Science Talent Search produced 49 research papers. Twenty-four finalists were selected, of which 13 were eventual state winners.

The Junior Academy is now operating on a regional meeting concept; the best papers from the regions are presented at the annual Junior Academy meeting which now meets on the same day as the Academy.

Library Committee. William A. Daily, reporting for the committee, announced Volume 83 of the *Proceedings* was mailed to 1077 members and Science clubs; copies were also sent to foreign and domestic exchange agencies. Volume 84 has been received from the printers and will be mailed shortly. Mr. Daily also reported on the use of library materials by others and on recent additions to the collection.

Publications Committee. No report.

Membership Committee. Donald J. Cook, Chairman, reported that the new membership application blank has been distributed to all division chairmen and chairmen elect. The Committee encourages all eligible persons to elect the Senior membership category. The advisability of requiring that at least one author of presented papers be a senior member was discussed but no action taken.

Fellows Committee. Benjamin Moulton, editor of *Proceedings*, presented the first copy of Volume 84 to President Patton. As Chairman of the Fellows Committee, Mr. Moulton presented the following motion:

Motion: That the following persons be elected Fellows of the Academy:

WILLIAM H. BESSEY

DARRYL P. SANDERS

ROBERT E. GORDON

EUGENE P. SCHWARTZ

WILLIAM P. McCAFFERTY

PHILIP A. ST. JOHN

Seconded and carried.

Invitations Committee. Philip A. St. John, Chairman, reported that the sites selected for the next three Fall Academy meetings are: 1976—Valparaiso University, 1977—Indiana University-Purdue University-Indianapolis, and 1978—Anderson College. The committee will entertain invitations for the 1979 and 1980 meetings.

Resolutions Committee. No report.

Necrologist. No report.

Parliamentarian. No report.

Science and Society Committee. Otto K. Behrens, Chairman, presented a brief history of the committee and described its proposed programs. He then presented the following motion:

Motion: That the Committee report be accepted, including approval of the following general procedures:

1. Requests for preparation of informative reports on scientific and technological problems.

Upon receipt of a proposal, it would be circulated to members of the Science and Society Committee, and a meeting would be called to assess the feasibility of the study. If a favorable feasibility report were rendered, a small panel of experts would be enlisted to undertake the study, to set up a probable time schedule, and to determine the probable out-of-pocket costs that might be incurred.

The chairman would then notify the requesting agency and clarify any unresolved problems, including the manner of funding the study. A written statement of understanding should be signed by an official of the agency and by the chairman and the President of the Academy.

The progress of the study and review of drafts would be monitored by the Committee. Upon completion and approval of the Committee, it would be sent to the requesting agency over the signature of the President. Any actions of this nature conducted by the Science and Society Committee would be reported to the Executive Committee in an Annual Report.

2. Preparation of an annual report on scientific or technological subjects that merit attention and possible policy action by state governmental agencies.

Suggested subjects would be solicited through the Academy Newsletter. One or more of these subjects would be chosen each year by the Committee. A small task force would be enlisted to prepare an informative, impartial report. The initial draft would be reviewed by the Committee, and after revision and approval by the Committee, would be sent to the Executive Committee for review and comments. A final draft would be prepared for approval of the Committee and presentation to the Academy. The report would be presented by the Academy President to the Governor, Lt. Governor, and members of the General Assembly. It should be published in the *Proceedings* and/or brought to the attention of the public through other media.

Seconded and *carried*.

Biological Survey Committee. Jack R. Munsee, Chairman, reported that the committee would hold its first meeting following the General Session of the Academy. The report of the committee for Volume 84 of *Proceedings* includes titles for the period 1973-74.

Emeritus Member Selection Committee. Howard R. Youse, reporting for the Committee, stated that eight individuals had requested and had been certified as eligible for Emeritus Membership.

Motion: That the persons recommended be approved as Emeritus Members of Academy (initial membership year shown in parentheses):

MAX W. GARDNER, Berkeley, California (1919)
THOMAS M. BUSHNELL, West Lafayette, Indiana (1922)
W. HUGH HEADLEE, Indianapolis, Indiana (1926)
SCOTT MCCOY, Indianapolis, Indiana (1928)
MERRITT J. MURRAY, Kalamazoo, Michigan (1929)
LEON GREENWALT, Goshen, Indiana (1946)
JOSEPH I. PERREY, Cincinnati, Ohio (1949)
E. W. SHRIGLEY, Indianapolis, Indiana (1950)
Seconded and *carried*.

Preservation of Natural Areas Committee. William B. Barnes, Chairman, reported that 37 nature preserves have now been established in Indiana (6,228 acres). Three new ones are:

1. Barker Woods Nature Preserve, Michigan City (32 acres).
2. Ropchan Memorial Nature Preserve, Orland (77 acres).
3. John G. Dobbs Memorial Grove Nature Preserve, Terre Haute (25 acres).

The latter preserve is the first preserve to be dedicated that is owned by a city park and recreation board. Portland Arch was dedicated on October 25, 1975 as a Registered Natural Landmark by the National Park Service.

Speaker-of-the-Year Committee. Frank A. Guthrie, reporting for the Committee, announced that Dr. Harold G. Cassiday, Professor-At-Large, Hanover College, had been selected Speaker-of-the-Year and would deliver the lecture at the General Session of the Academy.

Representative on Natural Resources Commission. Damian V. Schmelz presented a brief summary of the general activities of the Commission and described a typical monthly meeting.

Bicentennial Committee. John Favinger, Chairman, described recent activities of the committee and presented a number of suggestions for the Bicentennial as well as for the period leading up to the Academy Centennial in 1985.

Ad hoc Committee on Endangered Species and Flora Indiana Program. Theodore J. Crovello, Chairman, reviewed federal legislation on endangered plant species, suggested several possible future activities for the committee, and distributed a report proposing possible procedures for the Flora Indiana Program.

Motion: That the Executive Committee accept the Committee proposal to create a formal Flora Indiana Project, whose major purpose will be the continued maintenance and dissemination of information about the kind, quantity and distribution of the plant life of the State. The information accumulated would be maintained and disseminated in ways that are both convenient and efficient.
Seconded and *carried*.

Motion: That all committee reports presented be accepted.
Seconded and *carried*.

NEW BUSINESS

Benjamin Moulton presented the following:

Motion: That the Executive Committee authorize Dr. William Eberly of Manchester College to negotiate possible future publication of "Natural Features of Indiana" with the Executive Committee of Midland Naturalist, University of Notre Dame Press.
Seconded and *carried*.

Howard K. Youse presented the following:

Motion: That the Constitution of the Academy, ARTICLE VI, Sec. 4. The *Budget Committee* . . . be amended to add the following:
"(7) the chairman of the Academy Foundation committee."
Seconded and *carried*.

President Patton briefly reviewed the background of the amendments to the Constitution and By-Laws to be presented before the General Session for action.

Theodore J. Crovello presented the following:

Motion: That a resolution regarding virus Encephalitis in Indiana be accepted by the Executive Committee for presentation to the General Session of the Academy.
Seconded and *carried*.

Walter A. Cory requested that members of the Executive Committee furnish information, via forms provided, on persons responsible for disposal of hazardous chemical wastes at Indiana colleges, universities, and the larger high schools to the Department of Environmental Health and Safety at Indiana University.

Donald J. Cook, in behalf of the Membership Committee, presented the following:

Motion: That the Executive Committee be empowered to present for election as an Honorary Member of the Indiana Academy of Science the individual who has been elected to the Office of Governor of the State of Indiana. This election will be presented to the Academy membership at the first General Meeting following the Governor's election. In addition the name of the Governor will appear on the Title Page of *Part 1—The Work of the Academy*—in the

Proceedings for that year. His name will be listed under the name of the President of the Academy as an Honorary Member.

Carried.

Donald J. Cook, in behalf of the Membership Committee, presented the following:

Motion: That the Executive Committee present Governor Otis R. Bowen as an Honorary Member of the Indiana Academy of Science.

Carried.

The Chair was assumed by Damian V. Schmelz in order that President John B. Patton might present the following:

Motion: That the President of the Academy be empowered to appoint an historian and/or archivist for the Academy. Seconded. President Patton resumed the Chair for the ballot.

Carried.

Adjournment. The meeting was adjourned at 10:45 p.m.

Respectfully submitted,

ROBERT E. VAN ATTA, Secretary

MINUTES OF THE GENERAL SESSION

October 31, 1975

The Business Session of the 91st Annual Meeting of the Academy was called to order by President John B. Patton at 3:20 p.m. in Room 108, Gallahue Science Hall, Butler University, Indianapolis, Indiana.

Dr. Paul R. Stewart, Vice President of Academic Affairs, Butler University, welcomed the Academy on behalf of Butler University.

The Secretary of the Academy presented a summary of committee reports and informed the membership of official actions taken by the Executive Committee on April 25, 1975 and on October 30, 1975.

The names of individuals who were elected 1976 Divisional Chairmen and Chairmen-Elect includes:

ANTHROPOLOGY

Chairman:	BENJAMIN K. SWARTZ
Chairman-Elect:	EDWARD M. DOLAN

BOTANY

Chairman:	ROGER F. BONEHAM
Chairman-Elect:	GARY E. DOLPH

CELL BIOLOGY

Chairman:	LEE F. ELLIS
Chairman-Elect:	RALPH JERSILD, JR.

CHEMISTRY

Chairman:	JOHN H. MEISER
Chairman-Elect:	PANG-FAI MA

ECOLOGY

Chairman:	JOHN O. WHITAKER, JR.
Chairman-Elect:	THOMAS S. MCCOMISH

ENGINEERING

Chairman:	ALDO GIORGINI
Chairman-Elect:	MILTON E. HARR

ENTOMOLOGY

Chairman:	VIRGIL R. KNAPP
Chairman-Elect:	W. PATRICK MCCAFFERTY

GEOLOGY AND GEOGRAPHY

Chairman:	NEIL V. WEBER
Chairman-Elect:	MARK RESHKIN

HISTORY OF SCIENCE

Chairman:	WILLIAM R. EBERLY
Chairman-Elect:	GERTRUDE L. WARD

MICROBIOLOGY AND MOLECULAR BIOLOGY

Chairman:	HAROLD EDDLEMAN
Chairman-Elect:	DAVID C. MADSEN

PHYSICS

Chairman: ROBERT E. HALE
Chairman-Elect: ELMER NUSSBAUM

PLANT TAXONOMY

Chairman: ORLAND J. BLANCHARD
Chairman-Elect: VICTOR RIEMANSCHNEIDER

SCIENCE EDUCATION

Chairman: HAROLD H. JAUS
Chairman-Elect: JON R. HENDRIX

SOIL AND ATMOSPHERIC SCIENCES

Chairman: HARRY M. GALLOWAY
Chairman-Elect: LAWRENCE A. SCHAAL

ZOOLOGY

Chairman: THOMAS JOSEPH
Chairman-Elect: JOHN O. WHITAKER, JR.

The Secretary then presented the following motions:

Motion: That the individuals who have applied for membership in the Academy be elected to the types of membership for which they have applied. Seconded and *carried*.

Motion: That the individuals recommended by the Emeritus Member Selection Committee and approved by the Executive Committee be elected to Emeritus Membership. *Carried*.

Motion: That the individuals recommended by the Fellows Committee and approved by the Executive Committee be elected as Fellows of the Academy. *Carried*.

Motion: That the individuals nominated by the Membership Committee and approved by the Executive Committee

Mr. Eli Lilly

Governor Otis R. Bowen

be elected to Honorary Membership in the Academy. *Carried*.

The Necrologist, Fay Daily, reported the deaths of four members: Murvel R. Garner, Francis C. Schmidt, Edward Kintner, and Frank M. Setzler.

A constitutional amendment concerning standing committees was discussed. This amendment was approved by the Executive Committee at the 1975 Spring Meeting.

Motion: That the Academy amend the constitution through addition of the following paragraphs at the end of ARTICLE V, Section 1: (15) Preservation of Natural Areas. The Committee on the Preservation of Natural Areas shall consist of nine members appointed for three-year rotating terms from the fields of Botany, Geology-Geography, and Zoology, and with as wide a geographic distribution in the State as practicable. This committee shall serve as a channel through which suggestions made by members as to the conservation and preservation of

natural areas may be referred to the Executive Committee in the form of recommendations.

(16) Emeritus Members. The Committee on Emeritus Members shall take steps to implement ARTICLE II, Section 4, by recommending members eligible for this status.

Seconded and *carried*.

An amendment to the By-Laws concerning distribution of PROCEEDINGS was discussed. This amendment was approved by the Executive Committee at the 1975 Spring Meeting.

Motion: That the Academy amend the By-Laws through the addition of the *italicized* words in the following ARTICLES:

ARTICLE I, Section 6. Each *senior and sustaining* member is entitled to one copy of the Proceedings of the Academy, and any other publications of the Academy distributed to the membership of the Academy, that are published in the year for which dues have been paid.

ARTICLE I, Section 7. Former *senior and sustaining* members who were dropped for non-payment of dues may obtain one copy of the Proceedings, or other publications, published in a year in which they were inactive by either of two methods, provided copies are still available:

- a. They may pay the reinstatement fee and dues for the year of years of interest.
- b. They may purchase one or more copies at the established nonmember price.

Seconded and *carried*.

William B. Hopp presented the report of the nominating committee and placed the following slate of candidates for 1976 in nomination:

President-Elect:	CLARENCE F. DINEEN, 1976
Treasurer:	STANLEY L. BURDEN, 1976, 77, 78
Bonding Committee:	EARL A. HOLMES, Chairman, 1976 ROBERT M. BROOKER, 1976
Academy Foundation Committee:	CLYDE R. METZ, 1976, 77
Research Grants Committee:	RALPH A. LLEWELLYN, 1976, 77, 78, 79, 80

The nominations were closed and a unanimous ballot was cast for the entire slate.

The Chairman of the Resolutions Committee, William A. Daily, presented the following two resolutions which were adopted by the assemblage:

I. WHEREAS:

During the past summer there was the worst epidemic of mosquito-borne encephalitis ever recorded in the United States.

The State of Indiana led the nation in cases per capita with nearly 300 confirmed cases of St. Louis Encephalitis plus many more suspect cases.

BE IT RESOLVED:

That research on mosquito-borne encephalitis in Indiana and on vector control under Indiana conditions should be undertaken and supported by public health agencies and universities in Indiana.

BE IT FURTHER RESOLVED:

That copies of this resolution should be sent to the Governor of Indiana, the State Board of Health and the Indiana Agricultural Experiment Station.

- II. That the Academy members here assembled express their appreciation to Dr. Alexander E. Jones, President of Butler University, for all the courtesies which have been extended the membership of the Academy during this meeting. We are particularly grateful to Professors Philip A. St. John and David W. Osgood, Co-Chairmen of the Program Committee for their fine work in the preparation of the program. The facilities for all programs at this annual meeting were excellent, especially in the new Gallahue Science Hall and Holcomb Research Institute. Further the Academy members are appreciative of the address of Dr. Harold G. Cassidy, Indiana Academy of Science Lecturer-of-the-Year.

Harry G. Day introduced the Speaker-of-the-Year, Dr. Harold G. Cassidy, who presented an interesting, humorous, and thought-provoking lecture entitled "The Ecology of Knowledge."

The meeting was recessed at 5:05 p.m. and was reconvened at 6:30 p.m. with Donald J. Cook presiding at the annual banquet held in the John Whistler Atherton Center.

The Presidential Address entitled ". . . Such Quantities of Sand" was presented by John B. Patton in Room 108 of Gallahue Science Hall. The profusely illustrated lecture was interesting, informative and enjoyable.

Respectfully submitted,
ROBERT E. VAN ATTA, Secretary

FINANCIAL REPORT

JANUARY 1-DECEMBER 31, 1975

I. ACADEMY ACCOUNTS

	Income	Budgeted	Expenditure	Budgeted
Dues -----	\$ 6,380.00	\$ 7,370.00	-----	-----
Reprints: Vol. 82 -----	65.35	-----	-----	-----
Vol. 83 -----	2,678.03	3,000.00	\$ 2,616.45	\$ 2,750.00
Vol. 84 -----	1,575.96	-----	3,295.80	-----
Interest -----	958.49	1,100.00	-----	-----
Miscellaneous -----	6.00	-----	-----	-----
Secretary -----	-----	-----	397.34	600.00
Treasurer -----	-----	-----	208.66	250.00
General Office -----	-----	-----	246.93	250.00
Travel, AAS Dues, etc. -----	-----	-----	216.80	225.00
Membership Committee -----	-----	-----	183.55	150.00
Transfer to Administered Accounts -	-----	-----	3,800.00	3,800.00
Junior Academy (\$400.00)	-----	-----	-----	-----
Science and Society (\$200.00)	-----	-----	-----	-----
Natural Areas (\$0.00)	-----	-----	-----	-----
Library Binding (\$1,000.00)	-----	-----	-----	-----
Proceedings: Publication (\$1,500.00)	-----	-----	-----	-----
Proceedings: Mailing (\$200.00)	-----	-----	-----	-----
Publications: Clerical (\$500.00)	-----	-----	-----	-----
President's Fund -----	-----	-----	0.00	100.00
Newsletter -----	-----	-----	296.35	550.00
Speaker of the Year Honorarium ---	-----	-----	500.00	500.00
Program Committee -----	-----	-----	991.58	1,000.00
Publication Editor's Expenses -----	-----	-----	500.00	500.00
Youth Activities -----	-----	-----	32.14	50.00
Biological Surveys Committee -----	-----	-----	0.00	50.00
Representative to AAAS Meeting ---	-----	-----	250.00	250.00
Public Relations -----	-----	-----	13.62	100.00
Section Chairman Expenses -----	-----	-----	11.50	150.00
CPA Fees for Tax Return Preparation	-----	-----	400.00	550.00
Lawyer's Fees -----	-----	-----	380.00	200.00
Miscellaneous -----	-----	-----	10.00	100.00
	\$11,663.83	\$11,470.00	\$14,350.72	\$12,125.00

II. ADMINISTERED ACCOUNTS

	January 1 Balance	1975 Income	1975 Expenditures	December 31 Balance
Junior Academy -----	\$ 447.28	\$ 400.00	\$ 634.36	\$ 212.92
Science Talent Search -----	2,342.25	2,134.86	2,161.73	2,315.38
Science and Society -----	1,415.62	200.00	43.00	1,572.62
Research -----	378.07	4,676.53	4,768.00	286.60
Natural Areas -----	1,026.50	0.00	0.00	1,026.50
J. S. Wright Library -----	134.28	0.00	0.00	134.28
Lilly III Library -----	2,632.76	0.00	0.00	2,632.76
Lilly V Library -----	4,873.20	0.00	360.00	4,513.20
Library Binding -----	22.20	1,000.00	1,026.65	—4.45
Science Fairs -----	0.00	100.00	100.00	0.00
Publications:				
Proceedings -----	1,146.42	21,804.00	22,801.59	148.83
Mailing of Proceedings -----	589.32	200.00	209.89	579.43
Monographs -----	993.02	260.50	0.00	1,253.52
Natural Features -----	0.00	0.00	0.00	0.00
Clerical -----	0.00	500.00	0.00	500.00
	<u>\$16,000.92</u>	<u>\$31,275.89</u>	<u>\$32,105.22</u>	<u>\$15,171.59</u>

III. SUMMARY

	Academy Accounts	Administered Accounts	Total
Balance: January 1, 1975 -----	\$ 9,353.25	\$16,000.92	\$25,354.17
1975 Income -----	11,663.83	31,275.89	42,939.72
1975 Expenditures -----	14,350.72	32,105.22	46,455.94
Balance: December 31, 1975 -----	6,666.36	15,171.59	21,837.95

IV. BANK BALANCES (December 31, 1975)

First Bank and Trust Company, Indianapolis, Indiana -----	\$ 6,972.92
Great Western Savings and Loan, Los Angeles, California --	5,259.64
First Western Savings and Loan, Las Vegas, Nevada -----	9,605.39
	<u>\$21,837.95</u>

V. SUMMARY OF TRUST FUNDS

A. Foundation Account (00430-00-0)

Income cash balance (1/1/75) -----	\$	110.92	
Total dividends and interest for 1975 -----		998.63	
Disbursements for 1975			
Research grants -----	\$	300.00	
Transfer to principal cash -----		0.00	
	\$	300.00	-300.00
Income cash balance (12/31/75) -----	\$	809.55	\$ 809.55
Principal cash balance (1/1/75) -----	\$	695.14	
Total receipts for 1975 -----		1,790.80	
Total disbursements for 1975 -----		-2,000.00	
Principal cash balance (12/31/75) -----	\$	485.94	\$ 485.94
Market value of investments (12/31/75) --			\$18,269.75
Total value of account (12/31/75) -----			\$19,565.24*

*Carrying value is \$22,497.40

B. John S. Wright Fund (00430-01-9)

Income cash balance (1/1/75) -----	\$	44.45	
Total dividends and interest for 1975 -----		15,798.72	
Disbursements for 1975			
INB fee -----	\$	2,402.36	
Transfer to 00430-02-8 -----		10,753.30	
Transfer to Principal Cash -----		2,000.00	
	\$15,155.66	-15,155.66	
Income cash balance (12/31/75) -----	\$	687.51	\$ 687.51
Principal cash balance (1/1/75) -----		432.59	
Total receipts for 1975 -----		48,033.28	
Total disbursements for 1975 -----		-47,634.10	
Principal cash balance (12/31/75) -----		831.77	\$ 831.77
Market value of investments (12/31/75) --			\$531,061.80
Total value of account (12/31/75) -----			\$532,581.08*

* Carrying value is \$333,411.65

C. John S. Wright Invested Income Account (00430-02-8)

Income cash balance (1/1/75) -----	\$	386.77	
Total interest for 1975 -----		847.32	
Disbursements for 1975			
Transfers to principal -----	\$	1,043.73	
	\$	1,043.73	-1,043.73
Income cash balance (12/31/75) -----		190.36	\$ 190.36
Principal cash balance (1/1/75) -----	\$	175.15	
Total receipts for 1975 -----		36,797.03	
Disbursements for 1975			
Purchase of investments -----	\$12,000.00		
Research grants -----	4,300.00		
Proceedings, vol. 83 -----	9,200.00		
vol. 84 -----	11,000.00		
	\$36,500.00	-36,500.00	
Principal cash balance (12/31/75) -----	\$	472.18	\$ 472.18
Market value of investments -----			4,000.00
Total value of account -----			\$ 4,662.54

VI. NOTES

Membership Dues:

According to the Treasurer's records, the current status may be summarized as follows:

- 998 paid (71 student, 549 member, 17 family member, 245 senior member, 13 senior family member, 5 sustaining member, 1 sustaining family member), life (4), honorary (4), emeritus (75) and club (14) members
- 175 on file from 1974, but not yet paid for 1975
- 89 new members for 1975 (included in above totals)
- 23 previous members reinstated during 1975 (included in above totals)
- 98 members and clubs dropped for nonpayment of 1974 dues

Dues Structure for 1975:

- \$ 2.00 for student memberships
- 5.00 for memberships and club memberships
- 10.00 for senior memberships
- 25.00 for sustaining memberships
- 2.00 additional for family memberships
- 300.00 for life memberships
- 150.00-500.00 corporate memberships
- 50.00-100.00 institutional memberships
- 1.00 initiation/reinstatement fee (\$2.00 for family membership)

Savings:

The treasurer, from the total assets of both Academy and Administered accounts, has maintained sufficient funds in the checking account to pay current bills throughout the year; the remaining funds have been invested in savings certificates.

Certificates redeemed in 1975

1. (GWSL) \$5,000.00 invested at 6.00% April 1973; April 1975 redemption value \$5,636.49.
2. (GWSL) \$7,000.00 invested at 6.00% April 1973; April 1975 redemption value \$7,892.45.
3. (FWSL) \$2,000.00 invested at 6.50% April 1974; April 1975 redemption value \$2,126.26.

Certificates current

1. (GWSL) \$5,000.00 invested at 6.75% April 1975; 31 December value \$5,259.64; maturity at October 1977.
2. (FWSL) \$3,000.00 invested at 6.75% April 1974; 31 December value \$3,361.68; maturity at October 1976.
3. (FWSL) \$2,000.00 invested at 6.50% April 1975; 31 December value \$2,100.43; maturity at April 1976.
4. (FWSL) \$1,000.00 invested at 6.50% June 1975; 31 December value \$1,035.82; maturity at June 1976.
5. (FWSL) \$1,000.00 invested at 6.50% June 1975; 31 December value \$1,035.82; maturity at June 1976.
6. (FWSL) \$1,000.00 invested at 6.50% June 1975; 31 December value \$1,035.82; maturity at June 1976.
7. (FWSL) \$1,000.00 invested at 6.50% June 1975; 31 December value \$1,035.82; maturity at June 1976.

Reprints:

Reprint charges to authors for Vol. 82 have been collected giving a net profit to the Academy of \$100.83 in excess of printing costs. Reprint charges to authors for Vol. 83 are being collected with 1 billing outstanding for \$61.55 giving a net profit to the Academy of \$123.13 in excess of printing costs. Reprint charges to authors for Vol. 84 are being collected with 22 billings outstanding for a total of \$1,981.82 giving a net profit to the Academy (1975 and 1976) of \$261.98 in excess of printing costs.

Attorney Fees:

Ice, Miller, Donadio & Ryan of Indianapolis have been advising the Academy in matters concerning the reprinting and roles of various publications. The executive committee voted at the Fall Meeting of 1973 to delay the transferring of \$4,226.87 for attorney fees concerning the tax classification problems to the Academy operating funds from the J. S. Wright fund until these funds are needed for operating expenses.

Publications:

Sales include \$104.00 for *Proceedings* and \$260.50 for Monographs. The actual cost for publishing Vol. 83 of the *Proceedings* was \$11,478.66 of which the State of Indiana paid \$1,200.00 leaving a balance of \$10,278.66 to be paid from Academy funds. The actual cost for publishing Vol. 84 of the *Proceedings* was \$13,722.93 of which the State of Indiana paid \$1,200.00 leaving a balance of \$12,522.93 to be paid from Academy funds.

Research Grants:

Funds totalling \$4,768.00 have been awarded to D. F. Brakke (Zoology-IU), C. B. Douglass (Biology-PU), B. A. Fields (Anthropology-IU), L. R. Ganion (Physiology-BSU), J. B. G. Droessler (Anthropology-IU), J. E. Oliver (Geography-ISU), C. Olsen (Geology-IU), A. O. Priebe (Plant Sciences-IU), A. Ravindran (Industrial Engineering-PU), D. M. Sever (Biology-SMC), R. E. Siverly (Physiology-BSU), J. C. Tan (Biology-VU), and Madison High School of Ramsey (Bacteriology).

VII. BUDGET FOR 1976

The following budget was approved by the Budget Committee at their meeting at the Indiana State Library, Indianapolis, on December 13, 1975:

Academy Accounts**Anticipated Income**

Dues, Initiation and Reinstatement Fees	
(100 @ \$2, 650 @ \$5, 250 @ \$10, 75 @ \$0) -----	\$ 5,950.00
Interest on Savings -----	1,100.00
Reprint Charges to Authors -----	3,300.00
	\$10,350.00

Budgeted Expenditures

Secretary -----	\$ 500.00
Treasurer -----	400.00
General Office -----	250.00
Officer Travel, AAAS Dues -----	225.00
Membership Committee -----	200.00
President's Contingency Fund -----	100.00
Newsletter -----	500.00
Speaker of the Year Honorarium -----	500.00
Program Committee -----	1,000.00
Publication Editor's Expenses -----	500.00
Youth Activities Committee -----	50.00
Biological Surveys Committee (including Endangered Plant Species and Flora Indiana Project Committees) -----	150.00
Representative to AAAS Meeting -----	300.00
Reprint Charges to Academy -----	3,000.00
Public Relations -----	100.00
Section Chairmen Expenses -----	150.00
CPA Fees for Tax Return Preparation -----	500.00
Lawyer's Fees -----	250.00
Miscellaneous -----	100.00
Transfers to Administered Accounts -----	2,750.00
Junior Academy -----	\$ 300.00
Science and Society Committee -----	1,000.00
Natural Areas Committee -----	-500.00

Library Binding -----	1,000.00	
Proceedings: Publication -----	750.00	
Proceedings: Mailing -----	200.00	
		\$11,525.00
Endowment Funds		
Anticipated Income		
IAS Foundation -----		\$ 300.00
J. S. Wright Investment Income -----		15,500.00
		\$15,800.00
Budgeted Expenditures		
Bank Fee -----		\$ 2,700.00
Research Grants (\$6,000-\$350 AAAS) -----		5,650.00
Publications		
Proceedings, Vol. 85 (\$12,000-\$8,000 Ind —\$750 transfer) -----		3,250.00
Monograph #4 (\$12,000-\$1,500 Wright balance from 1975-\$1,200 sales) -----		(9,300.00)*
		\$11,600.00*
*Suggest waiting until later 1977 for more Wright balance, sales, etc. to justify this.		
Restricted Accounts		
Anticipated Income		
Research Grants Committee (AAAS) -----		\$ 350.00(part)
Science Talent Search (Tri Kappa) -----		2,000.00
Publications -----		300.00
Proceedings -----	\$ 50.00	
Monographs and Nat Feat -----	250.00	
		\$ 2,650.00
Budgeted Expenditures		
Research Grants Committee -----		\$ 350.00(part)
Science Talent Search -----		2,000.00
Publications -----		300.00
Proceedings -----	\$ 50.00(part)	
Monographs -----	250.00(part)	
		\$ 2,650.00

Respectfully submitted,
Clyde Metz, Treasurer

We, the undersigned, have audited the Treasurer's records for the Indiana Academy of Science for the year 1975 and have found them to be accurate and in order.

Curtis A. Dhonau
Thomas E. Mouzin

THE INDIANA JUNIOR ACADEMY OF SCIENCE

43rd Annual Meeting, October 31, 1975

MR. LAWRENCE E. POORMAN—Director—Department of Physics, Indiana State University, Terre Haute, IN.

MR. RAY LICHTENHAN—Student Director, Indiana University, Bloomington, IN.

COUNCIL—REGIONAL DIRECTORS

- Region I — Dr. M. Pettersen, Morton High School, Hammond
- Region II — Mr. Keith Hunnings, New Haven High School, New Haven
- Region III — Vacant
- Region IV — Dr. Keith Ault, Ball State University, Muncie
- Region V — Mr. Stephen Thompson, Crawfordsville High School, Crawfordsville
- Region VI — Vacant
- Region VII — Mr. James Schwengel, Harrison High School, Evansville
- Region VIII — Dr. John Moody, Indiana University—Southeast, New Albany

OFFICERS:

President—Mr. Brian McElwee, Marquette High School, Michigan City

Secretary—Mr. Bruce Robinson, Crawfordsville High School, Crawfordsville

The 43rd annual meeting of the Indiana Junior Academy of Science convened at 9:00 A.M., October 31, 1975, on the 3rd floor of the Holcomb Research Institute, Butler University. President Laura Fisher presided. An election of officers procedure was described by President Fisher since this was the first election following the adoption of the constitution. After discussion, nominees for president-elect and secretary-elect were named.

The Director made several announcements and welcomed over 90 students and sponsors to the annual meeting.

President Fisher then conducted an installation ceremony for President Brian McElwee and Secretary Bruce Robinson. President McElwee then presided over the paper presentations.

During lunch, the candidates-elect for offices in 1976 campaigned among conferees. After lunch, President McElwee conducted the election. Results were:

President-Elect: George Jones, Paoli High School, Paoli

Secretary-Elect: Cheryl Pauer, Morton High School, Hammond

Three Outstanding Junior Scientists were named. These young scientists will receive a one-year membership in the American Association for the Advancement of Science including a one-year subscription to *Science* the AAAS official journal.

OUTSTANDING JUNIOR SCIENTISTS

Lori Rhodes, East Noble High School, Kendallville

Stephen Budak, Marquette High School, Michigan City

Cassius Scott, Marquette High School, Michigan City

Due to a truly outstanding group of papers presented, a team of external judges will read papers presented and evaluate their merit along guidelines specified by the council. These evaluations, plus evaluations of adults present during the presentations will be decisive in selecting the presenter who will represent the Indiana Junior Academy of Science at the American Junior Academy of Science meeting in Boston in February, 1976.

Schools represented at the 43rd annual meeting were:

Paoli High School, Paoli

Crawfordsville High School, Crawfordsville

Floyd Central High School, New Albany

Marquette High School, Michigan City

North Harrison High School, Ramsey

East Noble High School, Kendallville

New Haven High School, New Haven

Carmel High School, Carmel

Morton High School, Hammond

There were ninety students, eleven sponsors, one parent, three college students, three council members, the Youth Activities Committee Director, the Science Talent Search Director and the State Director in attendance at the 43rd annual meeting.

Respectfully submitted,

LAWRENCE E. POORMAN, Director
Indiana Junior Academy of Science

Paper Presenters and Paper Titles Delivered at the 43rd Annual Meeting
of The Indiana Junior Academy of Science, October 31, 1975.

Presenters	Title
1. Melinda Boyd (Junior) North Harrison High School Ramsey, IN (Sponsor: Tom Book) R.R. No. 3, Box 479 Corydon, IN 47112	Determining Relative Effectiveness of Various Bacteriostatic Agents on Salmonella, Staphylococcus and Lactobacillus
2. Stephen Budak (Senior) Marquette High School Michigan City, IN 46360 (Sponsor: Dean Christakis) 326 Barker Road Michigan City, IN 46360	The Development of a New Cell Line: Microsurgical Fusion and Nuclear Transplantation of Normal Neoplastic Homokaryonic and Heterokaryonic Neuroblast Cells and the Systematic Analysis of the Fate of Bicellular Hybrids

- | Presenters | Title |
|---|---|
| 3. George Jones (Senior)
Paoli Jr.-Sr. High School
Paoli, IN
(Sponsor: Tom Anderson)
R.R. No. 1
Paoli, IN | An Analysis of Coliform Bacteria
at Five Selected Tributary Inlets
Along the Patoka River |
| 4. Timothy Piper (Senior)
Marquette High School
Michigan City, IN 46360
(Sponsor: Dean Christakis)
106 Western Avenue
Michigan City, IN 46360 | New Concept on the Biochemical Co-
ordination of the Murine Sarcoma
C-type RNA Tumor Virus: Anti-
viral Potential Anti-cancer Activity
of a Double Stranded, Poly A•Poly
U, Versus a Triple Stranded, Poly
A•Poly U•Poly U Polyribonucleo-
tide, by Intramolecular Bonding |
| 5. Lori Rhodes** (Junior)
East Noble High School
Kendallville, IN
(Sponsor: Virginia Rhodes)
Country Club Hills
Kendallville, IN 46755 | Antibiotics From Soil Microorgan-
isms: Isolation, Extraction, and Pur-
ification |
| 6. Cassius Scott*** (Senior)
Marquette High School
Michigan City, IN 46360
(Sponsor: Dean Christakis)
2821 Tilden Avenue
Michigan City, IN 46360 | In Vitro Immunization of Mouse
Spleen Cells and the Immunological
Roles of Interferon and Satellite
DNA: A Correlation Between Anti-
body Acceleration or Inhibition and
Cellular Cyclic AMP Levels Using
a Competitive Binding Protein |
| 7. Joseph Greer (Junior)
Morton High School
Hammond, IN
(Sponsor: Mary Pettersen) | The Isolation and Identification of
the Anaerobic Bacteria Clostridia
From Soil and Fecal Samples |
| 8. Teresa Bruner (Sophomore)
Paoli Jr.-Sr. High School
Paoli, IN
(Sponsor: Carroll Ritter)
R.R. No. 1
Orleans, IN | A Comparative Study of the Accu-
racy of the Daily Weather Forecast
Versus Predictions of the Farmer's
Almanac |
| 9. Barry Taylor (Senior)
New Haven High School
New Haven, IN
(Sponsor: Keith Hunnings)
4418 Sunrose Lane
New Haven, IN | Applying the "Diagonal Method" to
nth Order Determinants |

10. William Shaw (Senior) Studies in Galaxy Photography
Crawfordsville High School
Crawfordsville, IN
(Sponsor: Stephen Thompson)
2 Eastgate Drive
Crawfordsville, IN 47933
11. Mary C. Wombles* (Junior) Pollutants in Aggregate: Thermal
Floyd Central High School and Metallic Pollution As It Relates
Rt. 2, New Albany, IN 47150 to the Quality of Life of Selected
(Sponsor: Ray Weatherholt) Invertebrates
Rt. 2, Box 445G
New Albany, IN 47150

* Best paper award.

** 1st runner-up.

*** 2nd runner-up.

Nominations for Outstanding Junior Scientists Included:

- | | |
|-------------------|------------------------------|
| *1. Stephen Budak | 5. Mary Jo DeLong (Senior) |
| 2. Timothy Piper | R.R. 2, Paoli, IN 47454 |
| *3. Lori Rhodes | 6. Steven B. Barger (Senior) |
| *4. Cassius Scott | R.R. No. 1, Box 203-A |
| | Floyds Knobs, IN 47119 |

1975 Officers:

President—Brian McElwee (Senior), Marquette High School, Michigan City, IN

Secretary—Bruce Robinson (Junior), Crawfordsville High School, Crawfordsville, IN

1976 Officers:

President—George Jones

Secretary—Cheryl Pouer, Morton High School, Hammond, IN

BIOLOGICAL SURVEY COMMITTEE REPORT—1974-1975

JACK R. MUNSEE, Chairman, Indiana State University

MORRIS LEVY
Purdue University

DAVID S. WOODRUFF
Purdue University

GAYTON C. MARKS
Valparaiso University

WILLARD F. YATES
Butler University

VICTOR RIEMENSCHNEIDER
Indiana University, South Bend

FRANK N. YOUNG
Indiana University

J. W. REISING
Indiana State University
Evansville

(A, B, or C accompanying title refers to: Publication; Thesis on file; or Work in progress, respectively.)

- Biota: CRISMAN, T. L., and D. R. WHITEHEAD. 1975. Environmental history of Hovey Lake, southwestern Indiana. *Amer. Midl. Nat.* 93 (1):198-205. (A).
- Fungi: 1. ATHOW, K. L., F. A. LAVIOLETTE, and T. S. ABNEY. 1974. Reaction of soybean germplasm strains to four physiologic races of *Phytophthora megasperma* var. *sojae*. *Plant Dis. Repr.* 58:789-792. (A).
2. HASSELBRING, T. S., M. R. TANSEY, and M. A. JACK. 1975. Fungi associated with growing stalactites. *Mycologia* 67:171-172. (Indiana caves). (A).
3. HENNEN, JOE F. Purdue Univ. Uredinales of Indiana. (C).
4. WILCOX, J. R., F. A. LAVIOLETTE, and K. L. ATHOW. 1974. Deterioration of soybean seed quality associated with delayed harvest. *Plant Dis. Repr.* 58:130-133. (A).
- Algae: 1. BROOKS, A. E., and W. N. DOEMEL. 1975. The effects of a fluorescent whitening agent on the green alga, *Cosmarium*. *Proc. XII. Int. Bot. Congr. (Leningrad)*. In press. Abstr. (A).
- *2. BROOKS, A. E., and W. N. DOEMEL. 1973. The effect of sewage phosphorus reduction on algal growth potential of lake waters. *Proc. Indiana Acad. Sci.* 82:99. Abstr. (A).
3. DENNER, M., and J. REISING. Indiana State Univ., Evansville. Algal survey, ponds and lakes, Vanderburgh County, Indiana. (C).
- *4. DOEMEL, WILLIAM N., and AUSTIN E. BROOKS. 1973. A new algal assay to determine the growth potential of phosphorus containing natural waters. *Proc. Indiana Acad. Sci.* 82:98-99. Abstr. (A).
5. DOEMEL, W. N., and A. E. BROOKS. 1975. Detergent phosphorus and algal growth. *Water Res.* 9:713-719. (A).
- Tracheophyta: 1. BURGETTE, DANIEL L. 1975. Vegetational analysis of Portland Arch Nature Preserve, Fountain County, Indiana; comparing the Ohmann-Ream Method with Stratum Ranking. M.S. Thesis, Purdue Univ. 204 pp. (B).
2. JACKSON, M. T., and W. B. BARNES. 1975. Analysis of two old-growth forests on poorly-drained Clermont soils in Jennings County, Indiana. *Proc. Indiana Acad. Sci.* 84:222-233. (A).
3. LEVY M., and D. A. LEVIN. 1975. Genetic heterozygosity and variation in permanent translocation heterozygotes of the *Oenothera biennis* complex. *Genetics* 79:493-512. (A).

4. LEVY, M., and D. A. LEVIN. 1974. Novel flavonoids and reticulate evolution in the *Phlox pilosa*-*P. drummondii* complex. Amer. J. Bot. 61:156-167. (A).
5. LEVY, M., E. E. STEINER, and D. A. LEVIN. 1975. Allozyme genetics in permanent translocation heterozygotes of the *Oenothera biennis* complex. Biochem. Genetics 13:487-500. (A).
- *6. LINDSEY, A. A. 1973. Tornado tracks in the presettlement forests of Indiana. Proc. Indiana Acad. Sci. 82:181. Abstr. (A).
7. MARKS, GAYTON C. 1974. New county records for Porter and LaPorte Counties. Proc. Indiana Acad. Sci. 84:427. Abstr. (A).
8. RIEMENSCHNEIDER, VICTOR. Indiana Univ., So. Bend. The vascular flora of the Swamp Rose Nature Preserve, St. Joseph County, Indiana. (C).
9. SCHMELZ, D. V., J. D. BARTON, and A. A. LINDSEY. 1975. Donaldson's Woods: Two decades of change. Proc. Indiana Acad. Sci. 84:234-243. (A).
10. VON CULIN, H. J., and A. A. LINDSEY. 1975. Floristic change in the Ross Biological Reserve, 1950-1971. Proc. Indiana Acad. Sci. 84:216-221. (A).
- *11. VON CULIN, H. J., and A. A. LINDSEY. 1973. Two decades of vegetational change in the Ross Biological Reserve. Proc. Indiana Acad. Sci. 82:189-197. (A).

Protozoa:

1. GRIMES, G. W. 1975. Morphological discontinuity of kinetosomes during the life cycle of *Oxytricha fallax*. J. Cell Biol. 57:229-232. (A).
2. JOSEPH, THOMAS. 1974. *Eimeria indianensis* sp. n., and an *Isospora* sp., from the opossum, *Didelphis virginiana* (Kerr). J. Protozool. 21:12-15. (A).
3. JOSEPH, THOMAS. 1975. Experimental transmission of *Eimeria confusa* Joseph, 1969, to the fox squirrel. J. Wildlife Dis. 11:402-403. (A).
4. SONNEBORN, T. M. 1975. *Paramecium aurelia*. In Handbook of Genetics, Chap. 20:469-594. R. King, Ed. Plenum Press. N. Y. (A).
5. TAMAR, H. 1975. Movements of saltatory ciliates. J. Protozool. 22(3):45A (August). Abstr. (A).
6. TAMM, S. L., T. M. SONNEBORN, and R. V. DIPPELL. 1975. The role of cortical orientation in the control of the direction of ciliary beat in *Paramecium*. J. Cell Biol. 64:98-112. (A).

Platyhelminthes: JOSEPH, THOMAS. 1974. *Hymenolepis diminuta* in a gray squirrel from Indiana. J. Wildlife Dis. 10:164-165. (A).

Nematoda:

- *1. FERRIS, V. R., J. M. FERRIS, and C. A. CALLAHAN. 1972. Nematode community structure a tool for evaluating water resource environments. Purdue Univ. Water Res. Research Center Tech. Rept. 30. 40 pp. (A).
2. GOSCO, C. G., V. R. FERRIS, and J. M. FERRIS. 1974. Revisions in Leptonchoidea (Nematoda: Dorylaimida). *Leptonchus*, *Proleptonchus*, *Funaria*, and *Meylis* n. gen. in Leptonchidae, Leptonchinae. Purdue Univ. Agr. Exp. Sta. Res. Bul. 911. 32 pp. (A).
3. GOSCO, G. C., V. R. FERRIS, and J. M. FERRIS. 1974. Revisions in Leptonchoidea (Nematoda: Dorylaimida). *Tyleptus* in Leptonchidae, Tyleptinae; *Basirotyleptus* in Leptonchidae, Belonenchinae; and *Loncharionema* n. gen. in Leptonchidae, Xiphinemellinae. Purdue Univ. Agr. Exp. Sta. Res. Bul. 913. 25 pp. (A).
- *4. JOHNSON, S. R., V. R. FERRIS, and J. M. FERRIS. 1972. Nematode community structure of forest woodlots. I. Relationships based on similarity coefficients of nematode species. J. Nematol. 4:175-183. (A).

- *5. TJEPEKEMA, J. P., V. R. FERRIS, and J. M. FERRIS. 1971. Review of the genus *Aporcelaimellus* Heyns, 1965 and six species groups of the genus *Eudorylaimus* Andrassy, 1959 (Nematoda: Dorylaimida). Purdue Univ. Agr. Exp. Sta. Res. Bul. 882. 52 pp. (A).
- Arthropoda:
1. KEITH, JAMES H. 1975. Climatic and biotic studies of a terrestrial cave ecosystem in Indiana. Cave Res. Found. 1974 Annual Rep. 50-52. Abstr. (A).
 2. KEITH, JAMES H. 1975. Population and behavioral studies of a troglobitic isopod, *Asellus jordanii*, in a groundwater environment. Cave Res. Found. 1974 Annual Rep. 48. Abstr. (A).
 3. SCHMIDT, N. DAVID. Indiana Univ., Ft. Wayne. Soil arthropod community dynamics in three different successional communities. (C).
- Insecta:
1. BAKER, N. T., and R. L. FISCHER. 1975. A taxonomic and ecologic study of the Asilidae of Michigan. Great Lakes Ent. 8(2):31-91. illus. (A).
 2. BURTON, JOHN S. 1975. The deer flies of Indiana (Diptera: Tabanidae: *Chrysops*). Great Lakes Ent. 8(1):1-29. illus. (A).
 3. HILSENHOFF, W. L. 1975. Notes on nearctic *Acilius* (Dytiscidae), with description of a new species. Ann. Ent. Soc. Amer. 68(2):271-274. 3 figs. (A).
 4. HUFF, B. L. JR., and W. P. MCCAFFERTY. 1974. Parthenogenesis and reproductive biology in four species of the mayfly genus *Stenonema*. Wasmann J. Biol. 32:247-254. (A).
 - *5. KREKELER, CARL H. 1973. Cave beetles of the genus *Pseudanophthalmus* (Coleoptera, Carabidae) from the Kentucky Bluegrass and vicinity. Fieldiana (Zoology) 62:35-83. (A).
 6. MCCAFFERTY, W. P. 1975. Institutional insect collections in Indiana. Proc. Indiana Acad. Sci. 84:294-306. (A).
 7. MCCAFFERTY, W. P., and B. L. HUFF, JR. 1974. Parthenogenesis in the mayfly *Stenonema femoratum* (Say) (Ephemeroptera: Heptageniidae). Entomol. News. 85:76-80. (A).
 8. MCCAFFERTY, W. P., and A. V. PROVONSHA. 1975. Reinstatement and biosystematics of *Heterocloeon* McDunnough (Ephemeroptera: Baetidae). J. Georgia Entomol. Soc. 10:123-127. (A).
 9. STEIN, J. L., and W. P. MCCAFFERTY. 1975. Diagnostic tables to the long-horned grasshoppers and crickets of Indiana. (Orthoptera: Ensifera). Purdue Univ. Agr. Exp. Sta. Res. Bull. No. 921:1-20. (A).
- Pisces:
1. KARR, JAMES R. and O. T. GORMAN. 1975. Effects of land treatment on the aquatic environment. USEPA Special Publication on Non-Point Source Pollution. 31 pp. In press. (A).
 2. KARR, JAMES R. 1975. Stream basin and terrestrial environment factors in fish community structure. IN: Environmental Impact of Land Use on Water Quality: A Progress Report. USEPA-90519-75-006, pp. 47-61. (A).
 3. WILLEY, R. G., M. J. DOSKOCIL, and C. A. LEMBI. 1974. Potential of the White Amur (*Ctenopharyngodon idella* Val.) as a biological control for aquatic weeds in Indiana. Proc. Indiana Acad. Sci. 83:173-178. (A).
- Amphibia:
- JONES, G. S., and F. W. ZEIGLER. 1975. Salamanders (*Plethodon cinereus* and *P. glutinosus*) on a strip mine in west central Indiana. Indiana Audubon Quart. 53:8-10. (A).
- Aves:
1. MELCHIORES, M. A. 1975. Migration and feeding behavior of non-hunted and hunted geese on the Jasper-Pulaski Goose Management Zone. Master's Thesis. Purdue Univ. 138 pp. (B).

2. MUMFORD, R. E., and C. R. DANNER. 1975. An Indiana marsh hawk roost. Indiana Audubon Quart. 52:96-98. (A).

Mammalia:

1. FISHER, J. L. 1975. A direction photocell technique to monitor activity of volant vertebrates. Proc. Indiana Acad. Sci. 85. In press. (A).
2. JONES, G. S., and J. O. WHITAKER, JR. 1975. The fauna of a hibernation nest of a meadow jumping mouse, *Zapus hudsonius*. Canad. Field-Nat. In press. (A).
3. TAVES, DAN R. Indiana Univ., Ft. Wayne. Effect of accelerated daylength on timing of estrous, ovulation, and embryonic development in *Peromyscus leucopus*. (C).

Plant Pathology:

- PECKNOLD, PAUL C., WALTER R. STEVENSON, and DONALD H. SCOTT. 1974. A compilation of plant diseases and disorders in Indiana—1974. Proc. Indiana Acad. Sci. 84:71-84. (A).

* Off-year publication.

NECROLOGY

FAY KENOYER DAILY, Butler University

EDWARD KINTNER

Ney, Ohio
July 1, 1879

Elkhart, Indiana
April 1, 1975

A man of many talents, Dr. Edward Kintner, died April 1, 1975, in a hospital in Elkhart, Indiana. He had resided at the Peabody Home near North Manchester and was retired from Manchester College where he had been head of the Biology Department.

Dr. Kintner was born at Ney, Ohio, July 1, 1879. His formal education was delayed until he was ten years old, but he was tutored by his parents at home and had already completed the fifth reader when he started to school at Ney. Although his interests were wide, he had a special interest in natural science from grade school days and became interested in aquatic life through articles in a farm journal called *The Western Rural*. He was later to write articles on fresh water sponges and spiders found particularly over and near water.

He attended high school at Ney, Ohio, and walked three miles to school. He received an A.B. degree from Manchester College in 1912 and an honorary Sc.D. degree in 1938. He received an A.M. from Ohio State University in 1914 and spent summers at Indiana University in 1924, 1925, 1933 and 1934.

In 1898, he started teaching at 19 years of age in a one-room school south of Sherwood, Ohio, at \$35.00 a month. He taught in grade and high schools in Ohio until 1909 when he came to Indiana to Manchester College. From 1912 to 1950, he taught a wide variety of science courses at Manchester College and many consider him the father of the science program at that college. He also became a minister in 1900 and elder to the Church of the Brethren. He served in a number of churches in Indiana and Ohio. In 1965, Manchester College recognized Dr. Kintner's high achievements by naming a campus science building after him and one of his students Dr. Carl W. Holl. He was secretary of the faculty from 1920 to 1949 and member of the executive board from 1927 to 1942. He was also visiting professor at other universities and after retiring from Manchester at age 71, he taught at Indiana Univer-

sity Center at Fort Wayne, Indiana, for 12 more years finally retiring in 1963.

Dr. Kintner was married in 1903, and he and his wife, Glada, raised eight children. Remarkably, all seven sons became doctors while the daughter became a dietician. A tribute was paid to Dr. and Mrs. Kintner on their 65th wedding anniversary: "To live to an old age and to be married sixty-five years is not necessarily an accomplishment of one's own doing. However, to be companions in the teaching profession for sixty-five years, companions in the church ministry sixty-five years, and companions in the raising of a family of doctors is an accomplishment for which a married couple can be justly proud. This has been the fruitful life of Edward and Glada Kintner." (*Manchester College Bul.* 63(3):3, Dec. 1971.)

Dr. Kintner joined the Indiana Academy of Science in 1926, was honored as Fellow in 1932 and was an Emeritus member at death. He was very active in the society and served as vice-president in 1936. He served on the Membership Committee (1930's, 1950's). He was also Program Chairman in 1937, on the Invitations Committee as chairman and member, Junior Academy of Science Committee member, and was Divisional Chairman of Entomology for 1949. He gave papers at the meetings on spiders of the genus *Tetragnatha*, Indiana fresh-water sponges and notes on unearthing parts of a *Mastodon* skeleton near Peru, Indiana. He was also a member of the American Association for the Advancement of Science. Biographic sketches about him appeared in *American Men of Science*, *Indiana Scientists*, *History of the Church of the Brethren* (Indiana, 1952, pp. 346-347), *Alumni Edition of the Manchester College Bulletin* (May, 1960, p. 5), and was the subject of articles in the *Manchester College Bulletin* (V. 61, No. 2 and V. 64, No. 3).

Dr. Kintner was 95 years old when he died after many years of distinguished service to Manchester College and his ministry. A colleague wrote, "After such a lifetime of teaching and preaching, one which could have inspired both deep affection and widespread admiration, Dr. Kintner's family—blood and spiritual—must be quite a bit bigger than anyone suspects."

FRANK M (ARYK) SETZLER

Fremont, Ohio
September 21, 1902

Culver, Indiana
February 13, 1975

Dr. Frank M. Setzler died unexpectedly February 13, 1975, in his home in Culver, Indiana, on Lake Maxinkuckee. He had taken a walk that morning on the ice of the lake to view the local winter fishing situation, but returned home complaining of shortness of breath and soon died. His last act concerned his chief hobby, fishing, which he enjoyed very much accompanied by several close companions.

Dr. Setzler was a noted anthropologist and archeologist who had become Head Curator in the Anthropological Department at the Smithsonian Institution before retirement in 1960.

He was born at Fremont, Ohio, September 21, 1902, attending grade and secondary schools there. He left high school during the war years to work at the Union Carbon and Carbide plant laboratory in Fremont. When the plant was transferred to Cleveland, he returned to school in Fremont. In 1924, he went to Ohio State University to pursue a chemical engineering course, but the necessity for a summer job led him to apply for archeological excavation under Dr. Harry Shetrone's supervision. This interest finally superseded his interest in engineering and led to a career in archeology and anthropology. He retained a lasting interest from early study of Ohio mounds and the Hopewell Indian culture. He was assistant field director with the Ohio State Historical Society from 1925 to 1927. He transferred to the University of Chicago and received a Ph.B. degree in Anthropology in 1928, continuing graduate work there. In the summers of 1928 to 1930, he was field director for the Indiana Archeological Survey. He received an honorary Doctor of Science degree from Indiana University in 1971 for his early archeological work in Indiana as well as other expeditions. He studied the Adena culture exhibited in the Whitewater River Region.

He was assistant curator in the Division of Archeology at the U.S. National Museum from 1930 to 1935; acting head curator in the Department of Anthropology 1935 to 1937; and head curator 1937 to 1960 when he retired. He published many articles in the Indiana Historical Society publication, Smithsonian Institution bulletins, *American Anthropologist* and *American Physical Anthropologist*. Additional responsibilities included leading the Smithsonian Institution archeological expeditions to the southwest and Texas from 1931 to 1933 and to Louisiana from 1932 to 1933. He was also deputy leader of the joint Smithsonian Institution, National Geographic Society and Australian government Arnheim Land expedition in 1948. The participating scientists were of several disciplines and studied the lives and culture of the aborigines. Dr. Setzler was awarded the Franklin L. Burr prize by the National Geographic Society in 1950 for his part in this successful study. In other activities, he was a member of the advisory board and later the council of the National Parks Service.

In the latter capacity, he had gone on a field trip shortly before his death. He was a member of the National Resources planning board; anthropological representative on the National Research Council, vice-chairman of the division of anthropology and psychology; American Scientific Council; and Smithsonian Institution delegate to the American Science Congress in 1940. He also held a position with the Southeast Museum of North American Indians and was chairman of the board of directors of the Marshall County Historical Society.

Dr. Setzler joined the Indiana Academy of Science in 1929 while with the Indiana Archeological Survey and was an Emeritus member when he died. He also belonged to the A.A.A.S. (fellow), Anthropological Association (councilor and secretary), Society of American Archeology (councilor), Washington Academy of Science (vice-president and secretary), Anthropological Society of Washington (secretary and president), Sigma Xi, American Council of Learned Societies, Lions Club (Culver, Indiana) and Cosmos Club of Washington. He is listed in *Who's Who in the Midwest*, *Who's Who, American Men of Science* and *Directory of American Scholars*.

At retirement, Dr. Setzler and his wife built a home on Lake Maxinkuckee at Culver, Indiana, where Dr. Setzler entered local church and civic activities with his usual enthusiasm. He was often the speaker at events throughout the area drawing on his wide and various experiences for material. He also kept active in national affairs, serving as a member of the Beautification Program launched by Ladybird Johnson. He accompanied her on trips throughout the United States promoting this project. It was, then, a great shock to the Culver Community when death suddenly claimed this energetic man last February.

NEW MEMBERS—INDIANA ACADEMY OF SCIENCE—1975

- MR. HAROLD ALLISON, R. 4, Washington, IN 47501, LG
- MR. CARL H. ARMSTRONG, 5928 Pine Hill Dr., Indianapolis, IN 46236
- MR. JOHN A. BACONE, 751 S. Mattis, Champaign, IL 61820 LBT
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PRESIDENTIAL ADDRESS

"... SUCH QUANTITIES OF SAND"

JOHN B. PATTON, Indiana Geological Survey, Bloomington, Indiana 47401

The surface bedrock in the earth's land areas is mostly sedimentary, and the sandstones, which consist of sand grains cemented or otherwise lithified into solid form, are the second most common, after shales, of the sedimentary rocks. In additional huge tracts the surface bedrock, whatever it may be, is covered with unconsolidated sand (Fig. 1).

Sand is a product of weathering and winnowing. In simplest terms it is defined as a loose material consisting of small but easily distinguishable grains, most commonly of quartz, resulting from the disintegration of rocks. The phrase "most commonly of quartz" masks a host of variants. Many sands are a heterogeneous mixture of quartz and numerous other mineral and rock fragments. Some consist entirely of non-quartz minerals, and of these a number consist essentially of a single mineral. Sands occur in all hues and colors, and through a wide variety of chemical compositions, many of which have special economic uses.

Sand grains range in size from one-sixteenth of a millimeter to two millimeters. The next smaller size is termed silt, and the next larger sizes are called granules and pebbles.

The abundance and importance of sand are reflected in cultures past and present, in history, in political boundaries, in literature, and in our technology and economy. We do not have to seek far to understand the abundance of sand, and particularly quartz sand. Ninety-five percent of the earth's continental crust is granite, which in turn consists, by definition, of quartz and feldspar. Quartz is the most common single mineral in the crust, although the group of minerals called the feldspars is more abundant in total.

The earth's sand and sandstone deposits have been formed through some combination of the geologic processes called weathering, erosion, sedimentation, and lithification. Mineral and rock debris is sorted by the transporting agencies of running water, the wind, marine currents, and wave action. Larger fragments are reduced to sand size (or smaller) or left behind, and material finer than sand size is carried away to be deposited elsewhere. Stream action produces alluvial deposits, in many instances consisting of mixed sand and gravel, in channels, valleys, and floodplains. Wind energy forms aeolian deposits, in the form of dunes or sheet sands. And marine forces distribute sands on the sea floor and as beaches.

As an ingredient sand has been used throughout much of human history in the form of sandstone for construction (Fig. 2). Sandstones offered excellent characteristics of workability and are still widely



FIGURE 1. *Along the south shore of Lake Michigan, longshore currents and wave action deposit and remove beach sand in a never-ending cycle, and aeolian activity forms and modifies dunes landward from the beaches.*

used as dimension stone, but sandstone carving (Fig. 3) has become a lost art as concern about silicosis has developed with the use of power tools. The warm-hued sandstones fashionable today are colored by varying amounts of iron oxide. An old mining expression says that a pound of iron will color a mountain, and indeed the iron content of sandstone need not be high to lend rich tones.

Another use for sand in its native form is as the fine aggregate in mortar and concrete. Mortar is one of those unappreciated factors in the aesthetic satisfaction to be found in good masonry. The color and texture of the mortar, and the thickness and tooling of the joints, combine to give a total visual effect which is belatedly being taken into account by experts in architectural preservation. Mortars may be made from sands that are coarse or fine grained (or ungraded), sharp or rounded, and monochromatic or of mixed hue, and the possible differences in appearance are great. The wrong mortar is just as destructive to the total artistic result as is the wrong typeface in a book, but the effect is rarely diagnosed by the casual observer.



FIGURE 2. *St. Meinrad Archabbey in Spencer County illustrates nineteenth-century sandstone masonry at its best. Sand is also a principal constituent of the mortar and the chief ingredient of the stained-glass and other windows.*



FIGURE 3. *Winged dragons and elaborate scrollwork carved in sandstone frame the main entry to the Wood County Courthouse at Bowling Green, Ohio.*

For other purposes in which sand is used as an ingredient, texture and certain other initial characteristics are lost, and perhaps the best example is the use in glass and for other ceramic purposes. High-silica sandstone, consisting almost entirely of the mineral quartz, is the principal ingredient of both historic and modern glass. The other raw materials include oxides or carbonates of calcium and magnesium and such additional substances as feldspar, borax, soda ash, and salt cake, some of which serve as fluxes to reduce the melting temperature of the mix. Cullet (broken glass) is an essential constituent of the furnace batch. Each ingredient affects the character of the final product.

Glass is a commodity essential to our civilization, and possessed of remarkable qualities. It is almost completely inert, can be transparent or opaque, can be colored, blown, molded, cut, and engraved, and is remarkably cheap. To the homeowner, the architect, the artist, and of course, the gourmet, glass provides a multitude of amenities and conveniences. Scientists and teachers should remember their special debt to glass. In microscope, telescope, and camera (and in many new, complex instruments), the optical qualities of glass have made a unique contribution to knowledge (nor should we forget that universal blessing

—eyeglasses). We remember Newton's apple; another common object told his genius truths that no-one else had heard:

"In the beginning of the year 1666 . . ." he said (he was then 23) ". . . I procured me a triangular glass prism to try therewith the celebrated phenomena of colors . . ."

Philosophical Transactions vi, 3075

Biological and medical studies are accurate because glass can be sterilized. Chemical and physical studies rely on its capacity to be formed in accurate and complex laboratory shapes. The botanist depends on glass to transmit light while excluding cold and wind. We must ask ourselves whether modern science could have developed without glass.

The glass mirror deserves recognition, too, because it is much clearer than polished bronze, more convenient than the pond or pool which so entranced Narcissus, and gives us—at least outwardly—the gift of seeing ourselves as others see us.

The drinking glass, superseding the pail and dipper and the shared beer mug, is one of the countless uncelebrated factors in improving public health.

In addition to its use as an ingredient, sand is an agent and enabler for many of our needs and processes. We owe to it our ability to fabricate a wide variety of items used in the household, in the kitchen, in industry, and in transportation: bells, kettles, skillets, candlesticks, stoves, motor blocks, locomotive wheels, and, as the handbills for country auctions say "other articles too numerous to mention". The feature common to these and many others is that they are transformed from molten metal to a useful object in foundry processes. Modern molding sands must conform to very tight specifications and perform to extremely close tolerances. Imagine, if you will, a sand mixture that can be pressed to extremely detailed shape and hold this form while heavy molten metal fills the openings—all of the openings, not just some of them—without any collapse or change in shape of the mold. And then consider the requirement that the mold must separate cleanly from the casting, remembering that sand occupies space *within* the casting as well as around it, and the fact that if the body bakes to a firm, bricklike consistency it will be the casting that is broken instead of the mold. Early foundry sands, and indeed those used well into this century, were principally natural mixtures in which sand of just the right texture and the correct amount of binder gave the required wet strength, green strength, and dry strength at the various stages of the molding and casting process. To reduce the amount of milling and finishing required for more precise specifications, molding sands of finer and finer texture have come to be used. Modern foundry sands are mainly mixed products that begin with a clean and carefully graded quartz sand to which are added the other necessary ingredients, such as clay.

One of the reasons that quartz sand and other silicious sands are suitable for molding is that quartz is refractory: it will withstand high temperatures without deformation or alteration and without becoming part of the product. Because of its refractory character, sand is used

in the troughs through which molten metal is run from furnaces and smelters to other locations for casting or further processing (Fig. 4). Silica brick, made with sand, is one of the leading refractory substances for lining furnaces, kilns, cupolas, and other chambers for high-temperature processing, as is shaped dimension sandstone.

In volume, sand is the most extensively used of all abrasives. Natural sandstones in which the grains are firmly cemented together are used for grindstones, whetstones, and shaped abrasive tools. Sand is used even more in granular or powdered form. Common sandpapers consist of sand-size grains of quartz or feldspar or garnet cemented to a flexible backing. Sanding belts, sanding discs, and sanding blocks are merely variants in the manner of fabrication and use. The abrasive agent in many commercial cleansers and scouring powders is silica flour made by pulverizing quartz sand. The wiresaw used for cutting stone depends upon the abrasive quality of the sand or other granular material that adheres to the wet, moving wire.

The abrasives market has changed greatly within our time, and many of the industrial abrasives of the present day are synthetic materials or special blends of natural materials. The choice of abrasives for industrial processes is determined by some combination of the



FIGURE 4. The Indiana dune sands along the shore of Lake Michigan have been so useful for runner sand, engine sand, and other industrial uses, and especially for fill, that much of the remaining unspoiled duneland is treasured as State and National recreation and preservation areas.

method of use and the optimum hardness. Quartz is too hard for some of these purposes and not hard enough for others. A popular misconception exists that abrasives must be much harder than the materials that they are to abrade, but this is not true. Particularly where extremely fine and smooth finishes or polishes are desired, the abrasive should be softer than the material that is to be abraded; jeweler's rouge is an example. Most grinding and abrasive finishing processes are actually attrition; like the gingham dog and the calico cat, the two materials eat each other up, and it is the controlled relative rate that determines the quality of the product. A special variant of the abrasive action of sand is to be found in its use for traction aid, as under locomotive wheels and on snowy roads.

Having reviewed the uses of sand as ingredient and agent, let us consider sand as a barrier—political, geographic, and protective. The earth's deserts have been natural boundaries because they are barriers to tribal migration and invasion. The sandy deserts are more effective barriers than the rocky deserts; to the impediments of any forbidding terrane, the sandy desert adds the ultimate one—instability. Roadways cannot be maintained, and landmarks disappear. It is apparently inevitable that the barrier regions themselves, although intrinsically worthless, become the battlefields in which countless lives are lost fighting for land that neither adversary really wants but that each feels it must hold. The sand deserts have served as barriers to foot troops, horse troops, and mechanized forces. Rommel's mastery of desert terrane in North Africa was ended, in the view of some, not by superior forces but through an understanding of the desert made possible by the work of a British engineer named R. A. Bagnold, who published his knowledge and conclusions in a volume entitled *The Physics of Blown Sand and Desert Dunes*. The homely sandbag symbolizes Man's use of sand as a barrier against flood and gunfire.

At the far end of the spectrum from the hostile desert is the sand beach, almost a symbol of recreation. Beloved of swimmers, surfers, sunbathers, shell collectors, girl watchers, and small children with shovels and pails, the beach offers the two requirements for building sand castles—sand and leisure time. For the city child, the kindergarten sandbox brings indoors or to the playground a sample of the great natural world, along with the plasticine as a substitute for mud, and the rabbit in the cage. The sand trap on the golf course represents the human instinct to amuse ourselves by creating artificial difficulties.

History and literature demonstrate a curious human quirk: the tendency to admire gold—which is actually of very little use to us—more than humbler mineral products essential to our daily life. The statistical standard which I have chosen to describe this trait I have elsewhere called the Midas Index. It is derived by consulting the appropriate literary concordances and dividing the number of references to gold by the number of references to the essential mineral, in this case sand.

Chaucer speaks 12 times of sand and 184 times of gold; his Midas Index for sand is 15.3 (for clay it is 92). Shakespeare speaks 201 times

of gold—27 times of sand: *his* Midas Index for sand is 7.44. Milton's index is 10.2; Pope's 5.9; and Shelley's 2.5. Taking an average, we find that the 14th, 16th, 17th, 18th, and 19th centuries, in the persons of leading poets, show a Midas Index, for sand, of 8.26. Before any statisticians object to my cavalier juggling of random figures, let me remark that entire national policies have been and still are based on a smaller statistical sampling than this. I would sleep more easily at night if we had a national minerals policy based on so solid and scientific a foundation.

Sand is a useful daily servant, and without it we would lack many luxuries which we have come to consider necessities, but too often in our speech and writing we speak of it disparagingly. Sand is indeed an enemy to the mariner—though only one of many—as Shakespeare's few but graphic lines recall:

"I should not see the sandy hour-glass run
But I should think of shallows and of flats;
And see my wealthy *Andrew* dockt in sand,
Vailing her high-top lower than her ribs,
To kiss her burial . . ."

Merchant of Venice I i

and

". . . wrackt three nights ago on Goodwin Sands . . ."

King John V iii

Sand is also an enemy to the slogging infantryman—an enemy all too often associated with the broiling sun and, of course, thirst.

Shakespeare wrote

"How mightily sometimes we make us comforts of our losses".

All's Well That Ends Well IV iii

Perhaps we should reverse that line (so perverse and ungrateful is human nature!) and say "How mightily sometimes we make us losses of our comforts". We are annoyed, for example, by sand in the bathtub or sand in the gears; we should be grateful that sand has made it possible for us to *have* bathtubs and *have* gears.

Expressing the inexpressible concept of infinite number has daunted poets and scientists alike. A Hoosier homeowner, in October, might express infinite number in terms of fallen leaves, and in northern climes, infinite number might well be imagined in terms of the numbers of snowflakes which have fallen since Time's beginning. But in our symbolism, sand has been chosen to define most strikingly the infinity of number:

". . . many, as the sand which is by the sea in multitude . . ."

I Kings 4:20

"Who can number the sand of the sea . . ."

Ecclesiasticus 1:2

The innumerable grains of sand, and their small size, together exemplify a recognized truth: that many small things add up to great:

"Think naught a trifle, though it small appear;
Small sands the mountain, moments make the year"

Love of Fame, Edward Young

In an effort to embody, to visualize, the fleeting of Time, poets have written some of the most shining and most poignant lines in our noble literary tradition. In what terms does one imagine something invisible, inexorable, indefinable, omnipresent, which is known but not felt, measurable but eternal, by which our lives are ruled, of which each of us has been apportioned an unknown share?

Western poets have found in the hourglass a universal symbol. The handful of sand—out of the endless infinities of handfulls of sand—flowing at a measured rate in a container both brittle and unchangeable—expresses both the brevity of life and the immensity of Time. Boswell, in his *Life of Johnson*, wrote:

" . . . there is for every thought a certain nice adaptation of words which none other could equal, and which, when a man has been so fortunate as to hit, he has attained, in that particular case, to the perfection of language."

Just so, for many thoughts there is a certain nice adaptation of symbol which none other could equal, and which, when hit upon, attains a perfection of meaning. The hourglass is intuitively accepted as beautifully expressing Time's swift progress and Life's uncertain measure: a very unpretentious device to carry so solemn a meaning.

When we consider how our lives are blessed by sand as a material, as an ingredient, as an aid and assistant, as a protection, as recreation, and as a symbol, we must be most critical of the Walrus and the Carpenter for the lack of judgment and appreciation that they displayed when they " . . . wept like anything to see such quantities of sand".



ANTHROPOLOGY

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ABSTRACTS

Comments on a Newly Established Projectile Point Type. GARY A. APFELSTADT, Anthropology Museum and Laboratory, Indiana State University, Terre Haute, Indiana 47809.—Recently, the Lowe Flared Base point type of the Wabash River valley was divided to afford another type designation, the 'Allison Expanding Stem.' The exclusiveness of the latter point type is questioned based upon the information provided by the investigator and upon the information available from other studies.

The Kuester Site Blade Industry: A Preliminary Techno-Functional Analysis. GERALD W. KLINE, Department of Anthropology, University of Tennessee, Knoxville, Tennessee 37916.—Comprehensive analyses of prehistoric blade industries are rare for the Midstates region. With this being the case, a study was completed to enhance the understanding of production techniques and subsequent tool function. It is noted that two general functional classes are present in the sample: a) double-edged side scrapers, and b) knives. Comparison among the limited published reports of blade analyses suggests general similarities between southwestern Ohio sites and the Kuester site blade assemblage of southwestern Indiana.

Haley Mammoth Site, Vigo County: A Preliminary Report. ROBERT E. PACE, Anthropology Laboratory, Indiana State University, Terre Haute, Indiana 47809.—Excavations for a flood control dam along the Thompson Ditch east of Terre Haute recently uncovered bones of a mammoth, an ungulate, two rodents, and quantities of floral debris consisting mainly of coniferous wood. Samples of pollen and mollusks are being analyzed from five depositional strata that have produced UGa radio-carbon dates of 11480, 13850, 14985, 15725 and 15935. Mammoth bones recorded *in situ* include a mandible with teeth intact, fragments of the skull, parts of tusks, the hyoid bone, ulnae, radii, and ribs. A stratum containing the bones, coniferous wood and cones, and mollusks, was of a layered and brownish clay with inclusive pebbles and sand lenses. It produced a date of 13850 ± 195 years ago. No evidence of human presence was observed but the sequence of dates is believed to overlap with the arrival of Paleo-Indians. Analyses of floral, faunal and soil samples will contribute to knowledge of the climate and plant and animal communities immediately prior to and during the initial occupation of the region by Paleo-Indians.

The Developmental Cycle of Architectural Forms Among the Nahua of the Huasteca Region of Northern Veracruz, Mexico. PAUL JEAN PROVOST, Indiana University-Purdue University, Fort Wayne, Indiana 46805.—The Nahua Indians of the Huasteca region of northern Veracruz, Mexico live in a tropical forest biome. One of the uniquely adaptive features of their culture is the various architectural forms that are utilized by the Nahua to meet different environmental, ecological and socio-cultural needs. This paper will show how the different dwelling forms commonly found throughout Nahua villages actually represent different stages in an overall architectural developmental cycle. To do this, the paper will ethnographically describe the various different architectural forms, then trace their individual life histories, and then analyze their independent functions in the context of Nahua culture. The paper will then conclude by showing how house form, house life and architectural cycles are related to, or replicated in, other domains of the socio-cultural sphere.

Christmas in the Huasteca—Symbolic Forms in Nahua Indian Rituals. ALAN R. SANDSTROM, Indiana University-Purdue University, Fort Wayne, Indiana 46805.—One of the most elaborate and extensive ritual occasions observed by Nahuatl speaking people who inhabit the southern portion of the Huasteca region of east coast Mexico is called *Tlakatelilis*. The ritual is held continuously through day and night from December 20th to the 24th. Most outsiders, including non-Indian inhabitants of the region, equate *Tlakatelilis* with the Christmas celebration of national Mexican culture. Close examination of the symbolic forms in this complex ritual, however, reveals that it actually pertains to human and crop fertility.

Certain Christmas symbols have been incorporated into traditional Indian practices and these contribute to the misunderstanding of casual outside observers. This paper shows that Christian symbols used in Nahua rituals have been thoroughly re-interpreted and fitted to the Indian system of meanings. *Tlakatelilis* is shown to be a ritual that is based on traditional Indian beliefs and concerns that are quite distinct from those of Christianity.

Bar Room Behavior: An Analysis of Social Interaction in a Nightclub. CHARLES P. GALLMEIER, Indiana University at Fort Wayne, Indiana.—The author applies ethnographic field work methods to the study of social behavior in a popular local nightclub situated in a midwestern city—as viewed from the perspective of the bartenders. This study involved five months of a research strategy that is based on both involvement (participant observation) and detachment. The final analysis examines female/male relationships, as well as the patterns of male dominance in social interaction and briefly shows how these are linked to some general issues in anthropology. The first part of this report is concerned primarily with the division of labor in the nightclub. It basically emphasizes the difference between male and female roles. This principle, a sexual division of labor, is quite prominent at this particular nightclub. The men mix drinks, serve customers at the bar,

control the money, and manage the business transactions with the outside world. The women on the other hand, focus their concern on serving customers at tables. The second area explored in this study is the social structure of the nightclub itself. In this case, the formal social structure includes four categories of individuals: customers, employees, managers, and a special category, the nightclub band. Furthermore, the social network is also examined which shifts the attention from the formal social structure as a system to the way it is seen through the eyes of the bartenders. The final part of this study is concerned with the verbal performances of those who participate in the social life in the nightclub. Basically, this final area involves the cultural rules of speaking in a bar; that is, the use of fair and foul language and the proper way to order a drink.

Plants as Decomposition Vectors of Skeletal Human Remains. CHARLES P. WARREN, Department of Anthropology, University of Illinois at Chicago Circle, Chicago, Illinois 60680.—Research conducted at the U.S. Army Central Identification Laboratory, Sattahip, Thailand, has revealed that plants and their root systems constitute a complex of mechanisms and processes which function efficiently and effectively in causing the breakdown of the external and internal structure of human bone in both surface and burial sites. The plant activity is rapid and thorough, and the awareness of this phenomenon may lead to the revision of the theories which account for the paucity of the fossils of early man in the tropics.

Paleo-Indian and Archaic Distribution in the Lower Wabash Valley in Gibson and Posey Counties in Indiana. C. DEAN HIGGINBOTHAM, Department of Sociology and Anthropology, Purdue University, West Lafayette, Indiana 47906.—A recent survey of sites in Gibson and northern Posey counties has revealed a number of sites which have yielded fluted points. Three of these sites are on the floodplain. Many sites containing Archaic materials were also found on the floodplain or at the valley margins. It is suggested that the distribution of sites of these two traditions reveal a very old and enduring utilization of the floodplain environment.

Late Woodland Maples Mills Focus Populations in the Illinois Valley: Cultural Affinities and Biological Distance

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Abstract

The biological dimensions of cultural interaction are examined through biological distance analysis of skeletal series from six Late Woodland sites in the central Illinois and Mississippi valleys. Craniometric data are utilized. Series from the Gooden and Hagan sites, which have been associated ceramically with the Maples Mills focus, are compared to culturally distinguishable Late Woodland groups from the Erroke, Dickson and Ledders sites.

The Mahalanobis' generalized distance results generally support the pattern of cultural relationships hypothesized on the basis of associated archaeological assemblages. Geographical distance among the groups examined does not appear to be an important variable in explaining intergroup biological relationships.

Introduction

In 1937 Fay-Cooper Cole and Thorne Deuel distinguished a Late Woodland cultural complex in the central Illinois River valley which they termed the Maples Mills focus (2). They defined Maples Mills projectile point and ceramic types at the site of bluff-edge burial mounds on the Robert Gooden farm in Fulton County, Illinois. Two additional mortuary sites were later associated with the Maples Mills focus. Griffin, *et al.* (4) recognized Maples Mills occupations at the Hagan site in Schuyler County, Illinois, and Morse and Morse (6) tentatively associated burials at the Emmons site in Fulton County with the Maples Mills focus. Radiocarbon dates are not available from these sites; however, Griffin *et al.* (3) suggest a temporal range of approximately A.D. 700-900 for the Maples Mills complex.

Biocultural relationships of the Maples Mills people with other Late Woodland groups are not clear. The skeletal remains of these people offer a means of examining group affinities from a biological perspective. In the present investigation, biological variability is examined within and between skeletal series from the Gooden, Hagan and Emmons sites which are associated with the Maples Mills focus. In order to clarify the interactions of the Maples Mills groups with other Late Woodland groups, these three series are compared with skeletal series which have been distinguished ceramically from Maples Mills. The non-Maples Mills series used for these comparisons are from the Dickson, Erroke and Ledders sites.

The Dickson mortuary site overlooks the western floodplain of the Illinois River and the northern floodplain of the Spoon River in Fulton County, Illinois. Both Mississippian and Late Woodland components are present at the Dickson site. The series used in my analysis is from the Late Woodland component, which Harn calls the Sepo focus (5). Blakely has suggested a date of approximately A.D. 900 for initial Late Wood-

land use of the cemetery (1). The Sepo focus is therefore close to the Maples Mills focus in both time and space.

The Erroke series is from a bluff-edge mound overlooking the Mississippi River at Quincy, Illinois, in Adams County. It is a Late Woodland complex which is distinguishable from Maples Mills on the basis of ceramics. The archaeological assemblage associated with the Erroke burials has not been described in the literature to date.

The Ledders series is from the lower Illinois Valley region in Calhoun County, Illinois. Associated ceramics are typical of the Jersey Bluff complex, a Late Woodland variant in the lower Illinois Valley region. Radiocarbon dates from the Ledders site center around A.D. 1000.

Predicted Relationships

Four archaeologically distinct complexes are represented by the series examined: Maples Mills, Sepo, Jersey Bluff and Erroke. The Maples Mills focus is represented by three series: Gooden, Hagan and Emmons. Hypotheses of biological relationships among these groups were formulated on the basis of cultural relationships and geographical distance among sites. Approximate contemporaneity of sites is assumed on the basis of archaeological data.

If the cultural relationships suggested by ceramic analysis are valid, we should expect to see these relationships reflected in the biology of these groups. This assumes that social variables which restrict biological contact parallel differences in material culture. Thus genetic similarity is expected to correspond roughly to cultural similarity. The following hypothesis was formulated according to this model:

It is predicted that the Gooden, Hagan and Emmons groups, which share a ceramic tradition, will show more biological similarity to one another than they show to any one of the non-Maples Mills groups, Sepo, Erroke and Ledders.

Geographical relationships among sites (Fig. 1) provide an alternative model for predicting biological distance. This model assumes that the likelihood of intermarriage decreases with increasing spatial separation, and that cultural variables are not interacting to regulate gene flow. Two additional hypotheses are based on this model:

It is predicted that the Gooden group will be more similar in cranial morphology to the Dickson Sepo group than it is to the Hagan and Emmons groups, since the Gooden group is nearer to the Dickson site than it is to either the Hagan site or the Emmons site.

In terms of both land miles and river access, the groups on the Illinois River are located at a considerable distance from the groups on the Mississippi River (Fig. 1).

It is predicted that the three Maples Mills series and the Sepo series, which are all from sites on the Illinois River, will be more like one another than they are to either the Erroke or Ledders groups which are from sites located on the Mississippi River.

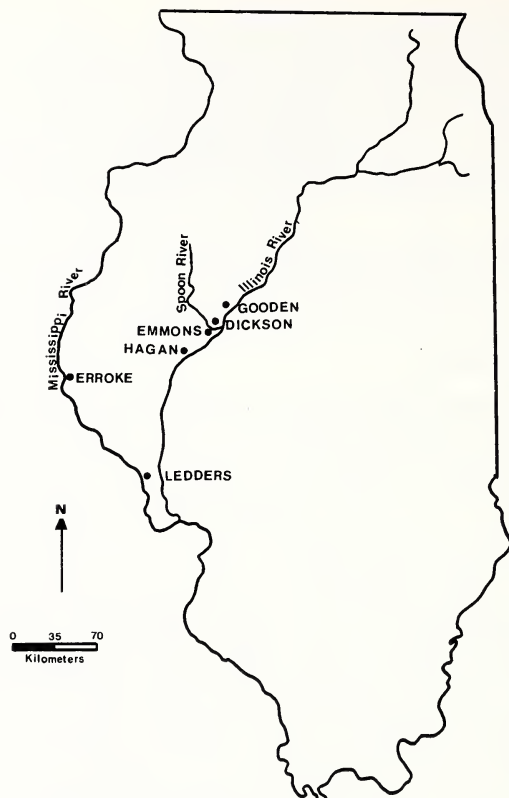


FIGURE 1. *Location of sites.*

Methods

Twelve cranial measurements and seven indices were used to estimate biological distance. Craniometric data were collected in part by Georg Neumann and in part by myself. I could not measure all of the material because much of the Gooden and Erroke series is no longer available for study. I remeasured a number of individuals previously measured by Neumann in order to standardize measurement technique.

Variables and sample sizes are indicated in Table 1. Selection of variables was to some extent dictated by the availability of data, a problem owing to the small size of the series. An 80% inclusion criterion was followed in selecting both variables and individual cases. Variables highly influenced by age and highly correlated (greater than .5) with another variable were not included. Group means were substituted for missing data. Only male crania were included since data available from female crania were limited.

Biological distance was estimated using multivariate discriminant analysis (BMD07M "Stepwise Discriminant Analysis") and Mahalanobis' generalized distance estimates (D^2). Measurements and indices were

analyzed separately. Results based on measurements were interpreted as reflecting predominantly size differences; results based on indices were interpreted as reflecting predominantly shape differences.

TABLE 1. *Male group means for cranial measurements and indices.*

Variable	Series					
	Gooden (N=14)	Hagan (N=11)	Erroke (N=7)	Emmons (N=2)	Sepo (N=12)	Ledders (N=5)
Measurements						
Glabella-opisthion length	182.07	182.73	180.14	176.50	184.50	180.80
Maximum breadth	137.29	138.18	138.86	131.00	137.92	140.00
Minimum frontal breadth	92.79	94.09	93.71	96.00	94.17	95.00
Basion-bregma height	140.00	143.09	142.00	135.50	145.75	140.40
Length of cranial base	104.93	102.82	103.86	101.00	110.50	104.40
Total facial breadth	136.29	136.64	138.00	135.50	136.08	137.60
Midfacial breadth	100.29	100.82	99.71	102.50	98.58	102.00
Upper facial height	75.07	76.91	76.29	73.50	74.42	73.40
Left orbital breadth (mf)	42.50	44.27	42.71	44.00	43.83	43.00
Left orbital height	34.36	35.18	34.29	34.50	34.92	34.20
Nasal height	53.57	55.09	54.29	54.00	55.00	53.60
Nasal breadth	25.36	26.18	24.57	24.00	25.58	26.00
Indices						
Cranial	75.53	75.61	77.10	74.20	74.81	77.44
Mean height	87.84	89.18	89.31	88.15	90.22	87.52
Transverse fronto-parietal	67.64	68.12	67.57	73.35	68.28	67.76
Upper facial	55.14	55.95	55.50	54.25	54.58	53.66
Transverse cranio-facial	99.31	98.87	99.16	103.50	99.03	98.26
Nasal	47.54	47.32	45.31	44.40	46.60	48.72
Left orbital (mf)	80.88	79.76	80.36	78.30	79.77	79.54

Results

The results of the biological distance analyses are summarized in Table 2 by Mahalanobis' distance estimates (D^2) derived separately from measurement and index data. The results based on measurement data are further illustrated by the plot of the first and second canonical variables derived in the discriminant analysis (Fig. 2). The first canonical variable, which explains approximately 64% of the total variation, is plotted along the abscissa; the second canonical variable, which explains an additional 29% of the total variation, is plotted along the ordinate. The ellipses enclose approximately 95% of the dispersion about the group means. Ellipses are drawn here for the Gooden, Hagan, Erroke and Sepo series, which were entered into the analysis as groups. Due to limited sample size the Ledders and Emmons crania were submitted to analysis as unclassified cases. As such they were omitted from the calculation of the discriminant functions but were classified into one of the four remaining groups according to the discriminant functions calculated for these four groups.

The groups plotted in Figure 2 in general show a considerable degree of shared variation. The overlap is particularly striking in the case of the Gooden and Erroke groups where the Erroke 95% dis-

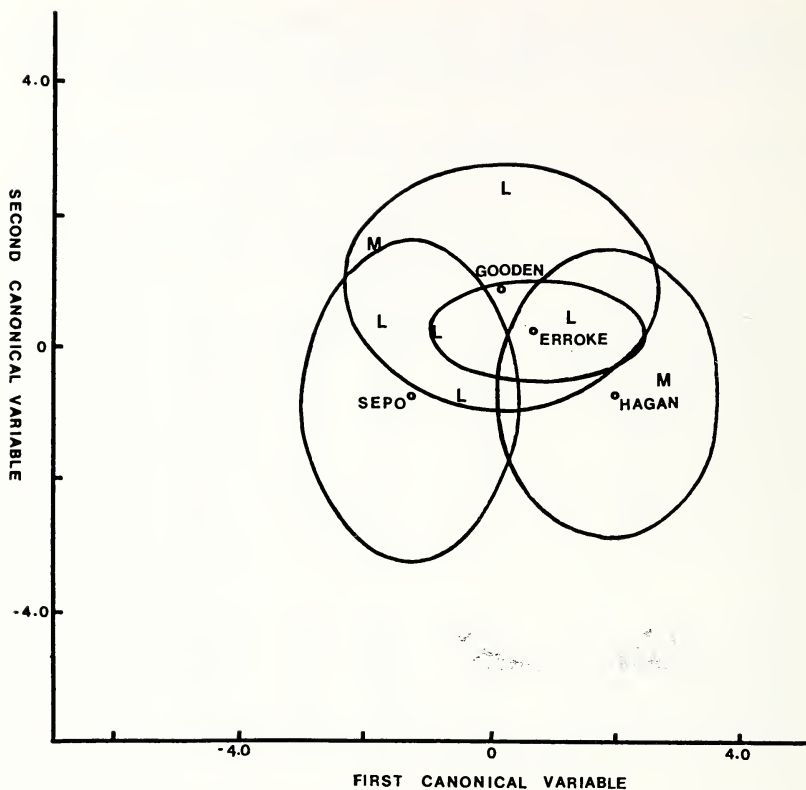


FIGURE 2. Plot of first and second canonical variables based on cranial measurements from the Gooden, Hagan, Sepo and Erroke groups. Ellipses represent 95% dispersion limits. Unclassified Ledders crania are indicated by L, Emmons by M.

TABLE 2. Mahalanobis' distance estimates based on cranial measurements (below diagonal) and indices (above diagonal).

Group	Gooden	Hagan	Erroke	Sepo
Gooden	---	.69	1.76	2.10
Hagan	6.01 ¹	---	.65	1.46
Erroke	1.86	3.66	---	1.85
Sepo	4.97	10.05 ²	5.61	---

¹ Significant at the .05 level.

² Significant at the .01 level.

persion limits are contained well within the 95% limits of the Gooden group. The small degree of variation within the Erroke group relative to the other groups is a problem here. It seems likely that the rather small Erroke sample does not approximate the total within-group variation of the Erroke population from which it was drawn. It is quite clearly similar to the Gooden group, however. Mahalanobis' D² estimates

of distance (Table 2) are low both in the analysis based on measurements and in the analysis based on indices.

The distinction between the Hagan and Sepo groups is marked. The Mahalanobis' estimate of distance between them when measurements are considered is statistically significant at the .01 level.

Both of the unclassified crania from the Emmons site, tentatively associated with the Maples Mills focus, are classified into groups which have been assigned to the Maples Mills focus. One of the Emmons crania is classified as Gooden, the other as Hagan.

The Gooden and Erroke groups show approximately equal degrees of overlap with Hagan and Sepo, and are clearly distinguished from them by the second discriminant function. The Gooden-Hagan Mahalanobis' D^2 estimate is statistically significant at the .05 level when measurements are compared. Examination of group means (Table 1) indicates that the Hagan crania are larger than the Gooden crania in every measurement except length of the cranial base, while indices do not differ greatly in the two groups. This suggests that size differences are more marked than shape differences between the Gooden and Hagan groups. Limited shape differences are indicated by the relatively small Mahalanobis' D^2 estimate which results from discriminant analysis of the indices (Table 2). Since size is more likely to vary with environmental factors such as nutritional level and disease stress (7), shape is probably a more stable reflection of the genome. Unfortunately, data necessary to test such an environmental difference between the Hagan and Gooden peoples are unavailable. If the size difference is in fact due to differences in the health status of the two groups, a relatively small biological distance between the two groups is suggested.

The distinction between the Hagan and Sepo groups is marked when cranial measurements are analyzed (Fig. 2); the Mahalanobis' estimate of distance between them is statistically significant at the .01 level (Table 2). The Hagan and Sepo groups are more alike in cranial indices than in cranial measurements. However, the difference in cranial morphology is not a case of one group simply being larger than the other. Shape as well as size differences are indicated.

The standardized weights of each variable included in the discriminant functions indicate that measurements of the facial skeleton, particularly the nasal and orbital areas, are the best discriminators among groups. Similarly, when indices are used as a basis for analysis the most heavily weighted indices in the discriminant functions relate facial dimensions. Since the greater part of the between-group variance in these analyses is accounted for by comparisons involving the Sepo group it can be inferred that the Sepo crania are distinct from the other groups in size and shape of the facial skeleton.

Discussion

It was predicted from the ceramic relationships that the Maples Mills groups, Gooden, Hagan and Emmons, would be more like one another biologically than they were to any one of the non-Maples Mills groups. This proposition is supported by the similarity in shape of the

Gooden and Hagan groups indicated by the relatively small D^2 estimates which result from analysis of indices. The classification of the two Emmons crania as Gooden and Hagan is also as predicted and supports the cultural affinity suggested for the Emmons site on the basis of archaeological data. The sizeable Mahalanobis' distances estimated between the Maples Mills groups and the Dickson Sepo group (Table 2) further support this hypothesis. However, the similarity in cranial morphology of the Erroke and Ledders groups to the Gooden group was not predicted. Sampling bias could account for this result; the Erroke and Ledders series are very small. Possibly the morphological similarity of the Erroke and Gooden series will be explained more satisfactorily when analysis of the cultural remains from the Erroke site is completed. With this exception, the hypothesis based on cultural relationships is supported; the groups described archaeologically as Maples Mills—Gooden, Hagan and Emmons—show considerable craniometric similarity.

Geographical relationships led to the prediction that the Gooden group would be more similar in cranial morphology to crania recovered from the nearby Dickson site than to crania from the more distant Hagan and Emmons sites. In this case geographical proximity is not reflected by biological proximity. The Gooden group is clearly more distinct craniometrically from the Sepo group than it is from the Hagan and Emmons groups. The existence of sociocultural barriers to biological exchange between the Sepo and the Maples Mills people is suggested in light of the relatively large biological distance between them despite close geographical and temporal proximity.

Spatial relationships also failed to predict biological relationships of the two Mississippi River groups—Erroke and Ledders—to the four groups from sites on the Illinois River. The Erroke and Ledders groups, while they are quite similar to one another, show considerable similarity in cranial morphology to the Gooden group. The distance of the Erroke group from the Hagan group is also small when indices are considered (Table 2). In addition, the groups on the Illinois River are less homogenous than predicted. In particular, morphological separation of the Sepo group from the other groups from Illinois River sites is contrary to expectations if geographical proximity is a significant factor in inter-group biological contact.

To summarize, the results presented here indicate that a simple geographical model does not adequately explain biosocial interaction among Late Woodland populations in this area. Cultural relationships, following largely from ceramic analysis, appear to be somewhat better predictors of biological distance. More extensive analysis of ceramic variation in the central Illinois region is needed to further our understanding of sociocultural interactions among Late Woodland populations. In addition, analysis of biological distance, demography, and epidemiology in larger skeletal series could add significantly to our appreciation of biological variability as a reflection of sociocultural relationships and human ecology among prehistoric inhabitants of the central Illinois Valley.

Acknowledgements

I wish to thank Dr. Jane Buikstra for permitting me to measure the crania from the Ledders site, and Dr. Robert Blakely for access to the Dickson Sepo data. I wish also to express appreciation to Professor Della C. Cook, Dr. Paul Jamison, and Dr. Robert Meier for reviewing various drafts of this manuscript.

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BOTANY

Chairman: ROBERT S. BENDA, Department of Biology,
Aquinas College, Grand Rapids, Michigan 49506

ROGER F. BONEHAM, Department of Geology,
Indiana University—Kokomo, Kokomo, Indiana 46901
was elected Chairman for 1976

ABSTRACTS

Meiosis in Variegated and Anthocyaninless Varieties of *Rhoeo*. THOMAS R. MERTENS and ROBERT F. BAKER, Department of Biology, Ball State University, Muncie, Indiana 47306.—A report by D. E. Wimber (1968) of two bivalent-forming clones of the anthocyaninless *Rhoeo spathacea* var. *concolor* coupled with the publication of a number of more recent studies of the typical form of *Rhoeo* spurred an investigation of seven clones of the ornamental *R. spathacea* var. *variegata* and four clones of *R. spathacea* var. *concolor*. All plants of both the variegated and the anthocyaninless varieties were found to possess the diploid number of twelve chromosomes and the structural hybridity characteristic of the common, uniformly green *Rhoeo* that possesses anthocyanin on the underside of its leaves. A number of previously unreported prophase I and anaphase I chromosome configurations were observed among the total of 5362 pollen mother cells scored for aberrant chromosome behavior. All plants were found to produce pollen with reduced viability, which was attributed to abnormal chromosome segregation during meiosis I.

Evolution of Laticifer Systems and Phylogenetic Trends in the Apocynaceae. LARRY R. YODER, The Ohio State University, Marion.—Laticifers are specialized secretory cells which produce the milky exudate found in plants such as milkweed, poinsettia and periwinkle. Laticifers occur either in articulated or non-articulated systems, and they may be branched or unbranched. Proposed theories of laticifer evolution cite examples from disjunct families with little regard for the systematic relationships of the plants involved. This is largely due to the apparent morphological stages in laticifer evolution whereas the systematic distribution of laticifer-bearing plants shows little evidence of laticifer evolution along any phylogenetic lines.

Two evolutionary theories have been proposed for non-articulated systems. One suggests that laticifers arose first as latex sacs restricted to mature tissues, and that they then appeared progressively earlier in development until their origins were restricted to the cotyledonary node of the embryo from which they branched during subsequent stem and root growth. An alternative theory proposes that laticifers first occurred in the embryo, and that laticifer systems of post-embryonic origin represent a secondary reduction characteristic of an advanced system.

Distribution of laticifer-bearing plants based on current phylogenetic schemes suggests polyphyletic origins for the various laticifer

systems. However, within the Apocynaceae, my study of laticifer initiation in *Vinca rosea* and comparison of initiation patterns and phylogeny in other members of the family indicate that in the Apocynaceae, laticifers evolved from a branched system initiated in the embryo to an unbranched system of embryonic and post-embryonic origins, and finally to an unbranched system of post-embryonic origins in the most advanced genera.

The Role of Computers in Teaching Synecology. GARY E. DOLPH, Department of Natural and Physical Sciences, Indiana University at Kokomo, Kokomo, Indiana 46901.—The type of experiment carried out in a synecology laboratory is strongly influenced by the amount of time and effort required to convert the raw data into an ecologically useful form. Experiments requiring complicated calculations are either avoided or illustrated using reduced data sets. The use of digital computers allows more complicated experiments to be carried out by reducing computational burdens to a minimum. In this presentation, two computer programs useful in teaching synecology are outlined. The first program calculates 7 parameters for each tree species in a sample stand. These parameters are: absolute density, dominance, and frequency; relative density, dominance, and frequency; and importance value. Input is in the form of unorganized raw data obtained by the point-centered quarter method. Any one of the 7 parameters calculated can be used to compare species composition in different communities. The second program uses the concept of Wisconsin comparative ordination to calculate the position of a series of sample stands in two-dimensional space. Input data can include any of the 7 parameters calculated using the first program. If environmental measurements are plotted at the sample points, the relationship between the sample stands and the environment can be studied. Copies of either program are available upon request.

Growth Response of *Cladophora* to a Thermal Effluent. ROBERT S. BENDA, Natural Science Division, Aquinas College, Grand Rapids, Michigan 49506.—*Cladophora*, especially *Cladophora glomerata*, is a green algae commonly found attached to rocks and other submerged firm substrata in the Great Lakes. It is considered a nuisance algae because its filaments of up to 60 cm in length are torn loose by wind and wave action and blown onshore where the algae accumulates in large mats.

During a two-year period (summers of 1972-73) of once through cooling (prior to installation of cooling towers in 1974) the seasonal growth patterns of *Cladophora* were observed in the thermal discharge area of the Palisades Nuclear Power Plant located on the shores of Lake Michigan, near South Haven, Michigan.

Cladophora was present in the area earlier in the spring and later in the fall months on the discharge structure than on surrounding substrates (at temperatures of 10 to 11°C). This growth pattern continued until mid-summer when the discharge temperature exceeded 26°C and *Cladophora* growth on the discharge structure ceased and died back although adjoining substrates supported fairly luxuriant growth of the algae.

Cladophora showed definite growth responses (both positive and negative) to the increased temperature of the thermal effluent which lengthened its growing season by several months in spring and fall, but which diminished its growth during the summer months. This agrees with laboratory documentation (1).

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Marine Invertebrate Fossils in Pennsylvanian Coal Balls from Southern Indiana

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Abstract

Coal balls from three localities in Warrick County, Indiana were found to have numerous marine invertebrate fossils intermixed with plant debris in their matrix. The shells of these animal fossils have been replaced by pyrite which makes it possible to separate them from the carbonate matrix.

Apparently this association of plant and animal fossils is indicative of marshes near tide water level which were occasionally inundated by storm waves which carried marine animals or their shells some distance inland. A similar process occurs today along the Gulf Coast Region of the United States.

Introduction

During the course of an investigation of coal ball plants from Coal V (Upper Des Moines Series) in southwestern Indiana the remains of animal fossils in some of the coal balls were noted. The occurrence of animal remains is so rare in coal balls the author decided to pursue the investigation further. This paper summarizes the results.

A number of localities yielded coal balls but only three mines, all in Warrick County, contained coal balls with animal fossils. The three sites are shown on Figure 1:

Locality K—Boon Coal Co. Mine, NW $\frac{1}{4}$, NW $\frac{1}{4}$, sec. 30, T.5S., R.8W., 4 miles west of Boonville (Boonville Quad.).

Locality G—Abandoned Houston Mine, SW $\frac{1}{4}$, SW $\frac{1}{4}$, sec. 11, T.5S., R.8W., 3 $\frac{1}{4}$ miles north of Boonville (Boonville Quad.).

Locality F—Abandoned strip mine, NW $\frac{1}{4}$, NW $\frac{1}{4}$, sec. 34, T.3S., R.7W., 1 $\frac{1}{2}$ miles northeast of Scalesville (Folsomville Quad.).

Mamay and Yochelson (15) reported marine animal remains in coal balls. They gave four collection localities for their material. One of these, Berryville, Illinois, is approximately 50 miles northwest of Boonville. The coal balls which Mamay and Yochelson reported were of four types:

1. Normal coal balls containing only plant fossils.
2. Homogeneous mixed coal balls containing unsegregated plant and animal fossils.
3. Heterogeneous mixed coal balls containing segregated plant and animal fossils.
4. Faunal coal balls containing only animal fossils.

The coal balls found during the course of this study were mainly of the normal variety. That is they contained plant material only. Those coal balls which contained animal fossils were mainly of the homogeneous variety. They contained plant and animal remains mixed together

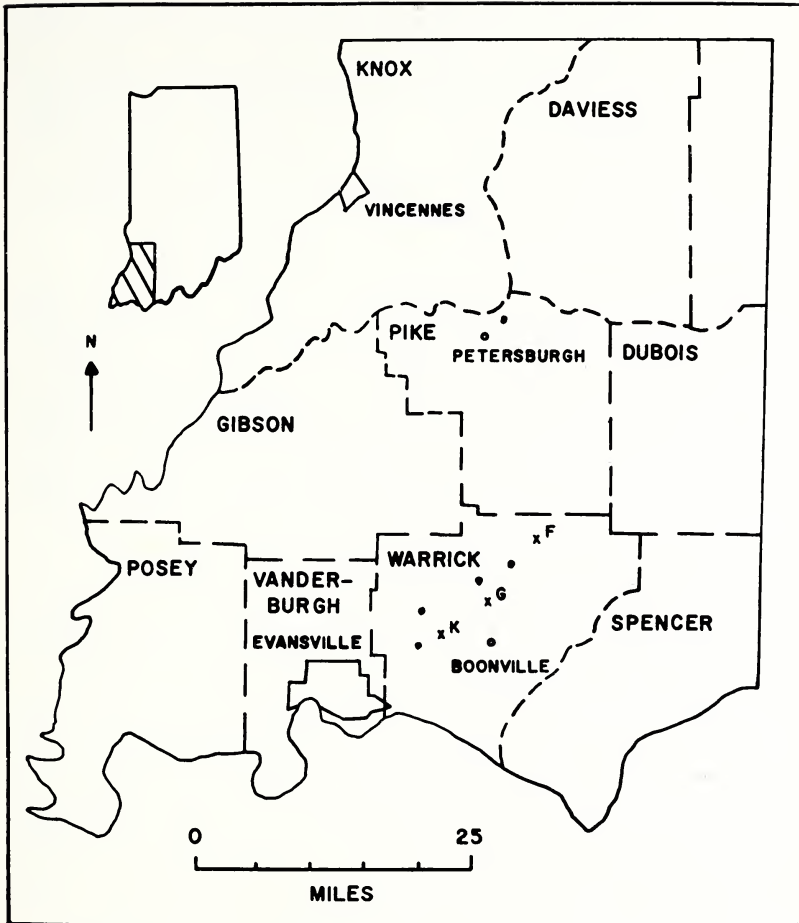


FIGURE 1. List of coal ball localities. The X's indicate sites where coal balls with animal fossils were collected. The back dots indicate where coal balls with plant remains only were collected.

throughout the coal ball matrix. This mixing was not complete however. Often in one area of the matrix there would be a preponderance of plant fragments while another part would contain a preponderance of animal remains. In many of the coal balls the color of the sediment indicated whether there would be a majority of plants or animals in a given part of the coal ball matrix. Areas where plant parts were in the majority were usually a light brown color. Areas where animal fossils predominated had sediment colors which ranged from dark brown to light black. One specimen (K5) is actually a small nest of normal coal balls. Incorporated within the cementing coaly matrix are some animal remains. A number of the faunal coal balls contain large amounts of iron sulfide in the matrix. In some of the coal balls

(K8, K37, G24, G29, F1) iron sulfide replacement of the matrix occurs along the periphery of the coal ball and has advanced toward the central portions with various degrees of replacement. The replacement order appears to have been first the fossil shells and second the carbonate matrix of the coal ball. The plant material has not been replaced to any significant extent, if at all. Pyritization has apparently had the effect of destroying plant matter rather than replacing it. In those coal balls which have large portions of the matrix replaced by iron sulfide there are significantly fewer plant fragments in the replaced areas than in the areas of carbonate matrix.

The occurrence of animal fossils in coal balls is apparently quite rare. In the present study not more than 5 per cent of the coal balls collected did contain animal remains. During the course of collecting the material it became clear that there was a subtle color difference of the outer matrix of many of the coal balls which contained animals. The coal balls were a somewhat lighter brown color than those which exclusively contained plant fossils. It may be that this color difference allowed me to collect a higher percentage of coal balls containing animal fossils than would have been the case with an entirely random collection.

Geologic History

The southwest region of Indiana lies along the eastern edge of the Eastern Interior Coal Basin which also underlies portions of northwestern Kentucky and central and southern Illinois. There are a number of coal seams presently being mined that were mined in the past. Ashley (1) proposed a scheme for naming the Indiana coal seams which was subsequently adopted in somewhat modified form by the Indiana Geological Survey. Essentially each principal coal seam is given a Roman numeral based upon its stratigraphic relationship to all other principal coal seams. In case one or more minor coal seams occur between two principal seams, these minor seams take the Roman numeral of the lower principal seam along with the suffix of a lower case letter. For example Coals Va and Vb occur between Coals V and VI, also Coal Va is below Vb.

Although coal has been mined in Indiana for approximately 150 years there have been very few paleobotanical papers on Pennsylvanian rocks of Indiana until the last twenty years. The first papers on Pennsylvanian paleobotany in Indiana were reports (19, 20) on some fossil tree trunks from Posey County. Lesquereux (12) published the first extensive paper on Pennsylvanian plants from Indiana. He also published the only paper on Pennsylvanian marine plants in Indiana (13). Although not intended as a research paper, Lesquereux (14) mentions Pennsylvanian plant specimens from Indiana in a number of fossil descriptions in what must be considered the first paleobotanical text published in the United States. White (23) published a paper on the flora of the Hindostan whetstone beds in the lower part of the Mansfield Formation of Morrowan age. Jackson published two papers (8, 9) on some floras from shale layers and sandstone layers within the Mansfield Formation. He correlated these floras with those of the

Pottsville Series in the Appalachian Region. Reed (22) published the first report on plant remains from Indiana coal balls found in Coal V. She described the anatomy of two specimens of *Pachytesta gigantea* Brongniart collected by Noé near Brownsville, Indiana. Benninghoff (3) published the first coal ball flora from material collected in Coal V near Petersburg, Indiana.

During the last decade paleobotanical research in Indiana has undergone a revival in comparison with the period following Lesquereux's studies. Baxter (2), Morgan and Delevoryas (17, 18) and Phillips (21) all published papers on plants from Indiana coal balls. It should be noted that the coal balls of Morgan and Delevoryas came from the Parker Coal of the Patoka Formation of Missouri Series age. Canright (5) published the only comprehensive modern study of Indiana plant fossils. He lists 93 collecting sites many of which are new. Guennel (6, 7) published two papers on the spores found in the Pottsville and Allegheny coals of Indiana. Wood (24) published a study of plant fossils found in ironstone concretions from a shale just above the Lower Block Coal in the lower part of the Brazil Formation in the Atoka Series. Boneham (4) did a study of an ironstone concretion flora from the Busseron Sandstone Member of the Shelburn Formation in the upper part of the Des Moines Series. The latest study on coal ball plants from Indiana was done by Judd and Nisbet (11). Although the authors do not say what coal seam the coal balls come from, the thesis of Judd (10) implies they are from Coal V. This paper is the first report of animal fossils in Indiana coal balls.

As stated earlier, all of the material for this report came from Coal V. Coal V or the Petersburg Coal of Indiana marks the top of the Petersburg Formation. This formation is in the Upper Des Moines Series of the Midcontinent Region. Coal V correlates with the No. 9 Coal of western Kentucky, the Harrisburg Coal of southern Illinois, the No. 5 or Springfield Coal of central Illinois and the Summit Coal of Iowa and Kansas (16).

Laboratory Techniques

Each coal ball was sawn in half in the laboratory. One of the sawn faces was polished and etched with dilute HCl. An acetate peel was prepared from the specimen by flooding the surface with acetone and rolling a piece of acetate film on it. This is standard technique used by many paleobotanists.

After the peel was removed it was quite easy to see if there were any invertebrates within the coal ball. The animal remains were nearly always replaced by iron sulfide. As a result they were unaffected by the acid etch and were not incorporated—within the acetate film. Their impressions could, however, be easily seen as clear outlines surrounded by the darker carbonate matrix which had been pulled off with the film.

As this study progressed it became obvious that the coal balls would have to be dissolved in order to obtain complete specimens for study. The decision was made to use dilute acetic acid rather than dilute hydrochloric acid since there was much less effervescence which might damage delicate forms and since one of the peels showed a

conodont it was best not to dissolve any more which might still have been in the coal balls.

Many of the coal balls dissolved satisfactorily in the acid. Some of those which contained a high percentage of iron sulfide were relatively unaffected and were not considered further. The sludge from the acid digestion was carefully screened through a 140-mesh sieve and washed. The fossils which remained on the sieve were picked off and placed in containers for further study.

Summary

It is unfortunate that none of the coal balls collected for this study were found in place. All were gathered from waste dumps around the mines. So the position of these coal balls within the coal seam is unknown. There is, however, little doubt that most were enclosed with the coal since most of them are at least partially enclosed within a thin veneer of coal. There is no reliable method of telling in the field whether a particular specimen is a normal coal ball or mixed coal ball. Occasionally a mixed coal ball if broken with a hammer will tend to split around some of the larger shell fragments. However, this is by no means a reliable guide. Each coal ball must be sawn through and examined in the laboratory before one can positively say whether or not it contains animal fossils.

The most probable explanation of how marine fossils came to be in the coal balls is that given by Mamay and Yochelson (15). Namely, the fossils were originally deposited offshore in a shallow bay. At various times storms coming onshore were violent enough to carry some of bottom mud into the low lying swamps which bordered this ancient sea. Some of the mud was dispersed in the waters of the swamp and the enclosed shells were incorporated within the vegetative mass which would ultimately become coal. If at a later date coal balls formed which included some of this vegetable material along with the invertebrate fossils the coal balls would be of the heterogeneous variety. On the other hand some of the mud may have not been dispersed completely but may have had enough cohesive strength to remain a discrete mass. If such mud balls were deposited within the vegetable debris this would explain how the homogeneous variety of coal balls were formed. Apparently a certain amount of intermixing of the marine mud balls with the mud from the swamp occurred since the zone of separation between the darker colored marine matrix and lighter colored non-marine matrix has a feathered appearance with stringers of one matrix trailing into the matrix of the other type.

Table 1 is a list of the specimens found in each coal ball which contained invertebrate fossils. The list does not contain quantitative information since I believe that adding numbers of specimens to the table would give a false sense of preciseness. The specimens are small species or the juvenile stages of larger species. Apparently these shells were subjected to winnowing action by currents which preferentially concentrated shells of a certain size range together in the bottom mud of bays along the coast. Therefore the percentage of a given species at

a locality probably has no relation to its frequency in the living population.

TABLE 1. *List of fossils in coal balls from Localities F, G, and K.*

	F	G	K
Protozoa:			
<i>Nubicularia</i> sp. -----	X	X	X
Echinodermata:			
Crinoid stems -----	X		X
Brachiopoda:			
<i>Mesolobus</i> sp. -----	X	X	X
<i>Marginifera</i> sp. -----		X	X
<i>Derbyia</i> sp. -----			X
Linoproductid indet. -----			X
Linguloid indet. -----	X		X
Orbiculoid indet. -----			X
Brachiopods sp. indet. -----	X	X	X
Mollusca:			
Cf. <i>Euphemites</i> sp. -----	X	X	X
Steinkern cf. <i>Girtyaspira</i> -----	X	X	X
Steinkern cf. <i>Shansiella</i> type A -----	X	X	X
Steinkern cf. <i>Shansiella</i> type B -----	X	X	X
Steinkern cf. <i>Donaldina</i> type A -----	X	X	X
Steinkern cf. <i>Donaldina</i> type B -----		X	X
<i>Glabrocingulum</i> sp. -----			X
Cf. <i>Cardiomorpha</i> -----			X
Pelecypods indet. -----		X	X
Orthoconic cephalapod -----			X
Arthropoda:			
<i>Pseudobythocypris pediformis</i> -----		X	X
<i>Amphissites centronotus</i> -----		X	X
<i>Pseudoparaporchites</i> sp. -----			X
<i>Bairdia</i> sp. -----			X
<i>Hollinella</i> sp. -----	X	X	X
Cf. <i>Hypotetrгона</i> sp. -----			X
Conodonts:			
<i>Idiognathodus</i> cf. <i>claviformis</i> -----			X
<i>Idiognathodus</i> cf. <i>delicatus</i> -----	X		
<i>Gnathodus</i> cf. <i>roundyi</i> -----	X		
<i>Hindeodella</i> sp. -----	X		
Barlike conodont indet. -----	X		
Platformlike conodont indet. -----	X		
Plantae:			
<i>Triletes auritus</i> -----	X	X	X
<i>Triletes triangulatus</i> -----	X	X	X
<i>Triletes glabratus</i> -----			X
<i>Monoletes</i> sp. -----			X
Seed coats indet. -----	X	X	X
Resin rodlets -----	X		

In the interest of completeness the specimen frequency should be mentioned since it is readily available. *Mesolobus* sp. specimens are the most common of the brachiopods. Whenever they are present in a coal ball, they compose the bulk of brachiopod specimens. The snails are the most common molluscs. Those present in the greatest numbers are cf. *Euphemites* sp. and cf. *Shansiella* spp. The most numerous of the ostracods is *Pseudobythocypris pediformis*. The conodonts are not

plentiful. But the most common are *Hindeodella* sp. and *Idiognathodus* cf. *delicatus*. Interestingly enough, practically all of the conodont specimens were found in coal balls from locality F. *Triletes auritus* and *Triletes triangulatus* are both plentiful megaspores in many of the coal balls.

Table 1 indicates that there are few differences in the fossils from the three localities. As Figure 1 shows, all the sites which had coal balls with invertebrate fossils are in Warrick County. It also shows other nearby coal ball sites which contain coal balls of the normal type—that is with plant fossils only.

The question of why animal remains are not found more frequently in coal balls is difficult to answer. Mamay and Yochelson (15) speculated upon this point also. They came to no very satisfactory conclusion and the author cannot either. The combination of a coal swamp nearly at tide water level on a coast subject to hurricanes does not seem to be a particularly unusual environment. Apparently there must have been other factors which are not yet recognized since coal balls containing animal fossils are rare.

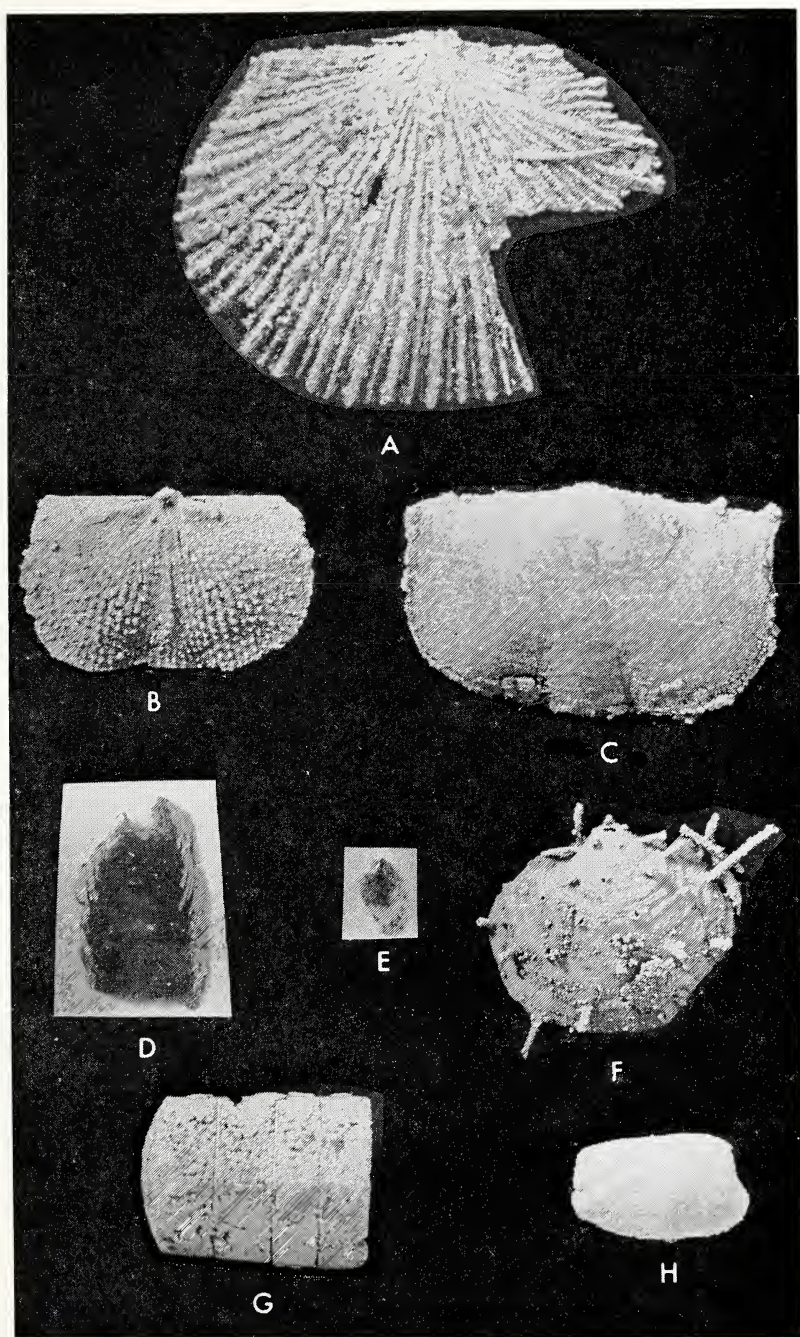
Acknowledgements

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PLATE 1

All figures X6

A. *Derbyia* sp., IU 12150; B. *Mesolobus* sp., interior of brachial valve, IU 13351; C. *Mesolobus* sp., IU 13352; D. Linguloid brachiopod, IU 13353; E. Orbiculoid brachiopod, IU 13354; F. *Marginifera* sp., IU 13355; G. Orthoconic cephalopod, IU 13356; H. Cf. *Cardiomorpha* sp., IU 13357.



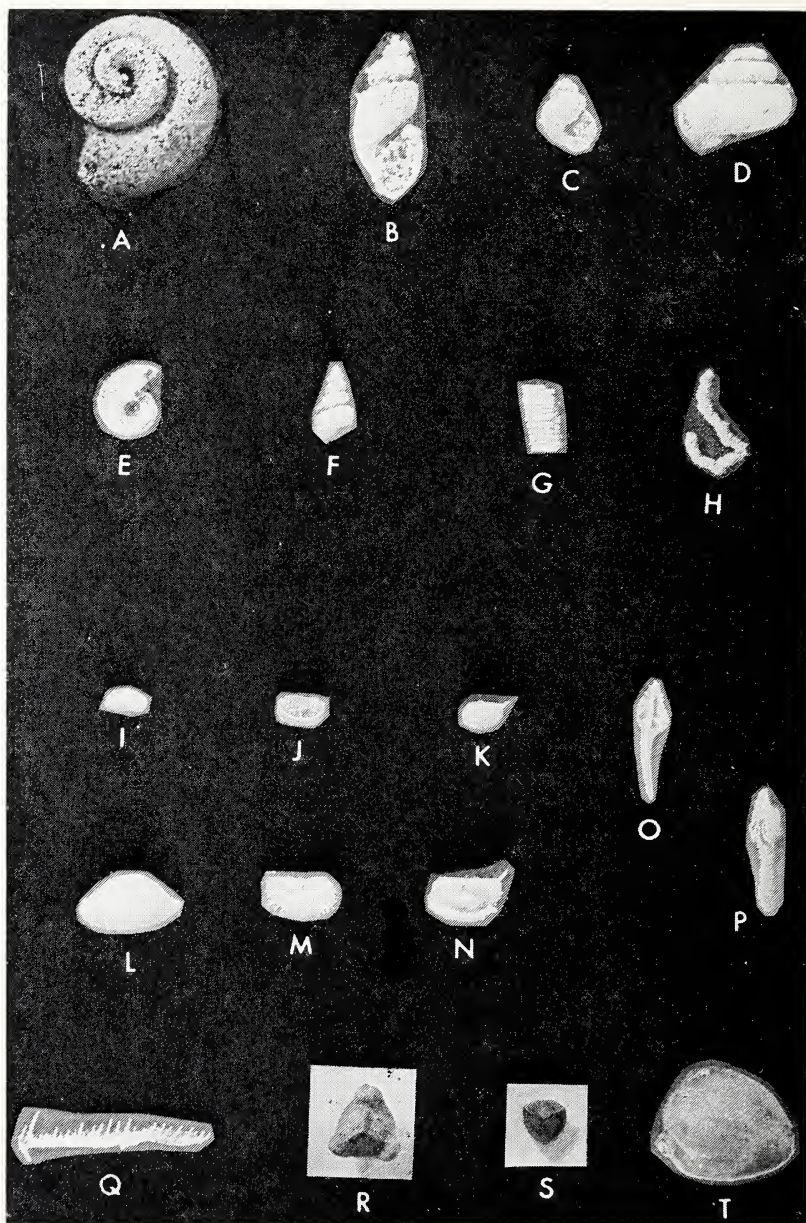


PLATE 2

All figures X6 unless otherwise specified.

A. Steinkern cf. *Shansiella* type B. IU 13358; B. Steinkern cf. *Girtyspira* sp., IU 13359; C. Steinkern cf. *Shansiella* type A, X9, IU 13360; D. Steinkern cf. *Donaldina* type A, IU 13361; E. cf. *Euphemites* sp., IU 13362; F. Steinkern cf. *Donaldina* type B, X7, IU 13363; G. Crinoid stem, IU 13364; H. *Nubicularia* sp., IU 13365; I. *Pseudobythocypris pediformis*, X9, IU 13366; J. *Amphissites centronotus*, X9, IU 13367; K. *Pseudoparaporchites* sp., X9, IU 13368; L. *Bairdia* sp., X9, IU 13369; M. *Hollinella* sp., X9, IU 13370; N. *Hollinella* sp., X9, IU 13371; O. *Gnathodus* cf. *roundyi*, X9, IU 13372; P. *Idiognathodus* cf. *delicatus*, X9, IU 13373; Q. *Hindcodella* sp., X9, IU 13374; R. *Triletes auritus*, IU 13375; S. *Triletes triangulatus*, X9, IU 13376; T. Seed coat, IU 13377.



PLATE 3

All figures X1

All coal ball figures are made from negative prints in order to enhance the contrast between the invertebrate fossils and matrix. The disadvantage of this photographic technique is that it lessens the contrast between the plant fossils and matrix.

A. Coal ball F9 is a heterogenous, mixed coal ball. Note the darker matrix in the bottom one-third. This portion contains plant fossils and very few animal remains. The rest of the coal ball contains abundant animal remains. The two matrices have different colors and this specimen shows quite well that the bottom muds which formed these coal balls were not always homogenized before lithification; B. A portion of coal ball K40. This is a homogenous, mixed coal ball. It mainly contains animal fossils but there are some plant fossils as well; C. Another portion of coal ball K40. This was a nest of small coal balls cemented together by the surrounding coal.

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Ultrastructural Changes of Chloroplasts in Aging Tobacco Leaves

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ABSTRACT

In chloroplasts of mesophyll cells in senescing tobacco leaves, the first indication of aging is the formation of osmiophilic globuli. Concurrently, osmiophilic material accumulates in the cytoplasm adjacent to chloroplasts. Subsequently, starch grains and granal structure are lost. During advanced stages of disintegration, chloroplasts contain prominent osmiophilic globuli. Finally, even these plastoglobuli disappear, and all that remains in the cell are small, ill-defined membrane whorls.

Introduction

Chloroplast biogenesis has been extensively studied (reviewed: 17, 28). Chloroplast precursors contain vesicles, tubules, tubular aggregations (prolamellar bodies), and membrane-bounded inclusions, all of which are involved in synthesis of photosynthetic lamellae (reviewed: 31). Developing plastids also contain lipid droplets (plastoglobuli) which may function in lamellar formation (3, 34). The formation of large plastoglobuli is the most conspicuous and indicative change during chloroplast senescence (8). They are thought to be accumulation sites of membrane breakdown products during chloroplast degradation (5, 16, 18, 19, 20). This study examines plastid aging in tobacco leaves and describes final stages involving degradation of plastoglobuli and appearance of membrane whorls, stages which have not previously been described.

Materials and Methods

Tobacco plants, *Nicotiana tabacum* L. var. Beltsville C, were grown in the greenhouse. Leaves of varying age (partially expanded, fully expanded, yellow-green, and yellow leaves) were taken, beginning at 15 mm leaf primordia, from the 5th, 9th, 15th, and 18th nodes of plants approximately 50 cm in height.

Tissues from the mid-laminar region, between the midrib and leaf margin, were cut into 1 mm squares and fixed at room temperature in 3% glutaraldehyde in 0.05 M potassium phosphate buffer, pH 6.8. The tissue pieces were then rinsed in buffer and postfixed in 2% osmium tetroxide in buffer. All fixations were started at eight A.M. After dehydration in a graded series of ethanol followed by propylene oxide, specimens were embedded in araldite-epon (27). Thin sections were stained with uranyl acetate followed by lead citrate and examined with a Hitachi HU-11-B-2 electron microscope.

Results

In leaves expanded approximately two thirds maximum size, the chloroplasts were small (1-3 μ long) and elliptical in profile (Fig. 1).

The grana and intergrana lamellar systems were not elaborately developed. Starch grains were present in most chloroplasts.

Conspicuously larger chloroplasts (4-8 μ long) were found in fully expanded green leaves. At this stage, the thylakoidal system was highly developed. Large starch grains distorted lamellar structure and disoriented the external profile of chloroplasts (Fig. 2). Nearly all chloroplasts contained plastosomes (inset, Fig. 2), vacuole-like areas containing an electron-opaque matrix (see 2). Cytoplasmic pockets were occasionally present in these mature plastids; however, they were more common in proplastids (unpublished observations, see also 35).

Chloroplasts in yellow-green leaves had greatly enlarged plastoglobuli which disrupted lamellar structure and contained few starch grains (Fig. 3). Plastosomes were not observed in these chloroplasts. In the cytoplasm, adjacent to chloroplasts, were dense, osmiophilic deposits. Particularly large deposits occurred in the region between the chloroplast and cell wall.

In senescent, yellow leaves, plastids were small (1-2 μ long) and contained many, large plastoglobuli, no starch grains, and few lamellar remnants. Often, cytoplasmic membranes in concentric whorls were associated with these aged plastids (Figs. 4 and 5). Even in this late stage of degeneration, the plastid envelope, tonoplast, and plasma membrane remained intact (Fig. 4). Discontinuities were evident in the tonoplast at the same time that plastoglobuli appeared to be partially degraded (Fig. 5). In a later stage of chloroplast breakdown, the plastid envelope was discontinuous and the plastoglobuli were further degraded. Fully senescent cells were devoid of contents except for a membrane (probably plasma membrane) along the cell wall (Fig. 7) which was characterized by small membrane whorls and osmiophilic deposits (Fig. 6).

Discussion

In plant cells, the symptoms of aging are usually expressed first in the chloroplasts (8). The most conspicuous change is the deposition of osmiophilic substances in the plastid stroma. According to Arnott and Harris (2), tobacco chloroplasts contain two types of suborganelles, plastoglobuli and plastosomes, which act as lipid repositories.

During degeneration of tobacco chloroplasts, plastoglobuli increase in both number and size, an event reported in other studies (15, 22, 26). The closeness of plastoglobuli to thylakoids (5, 11) and their appearance as thylakoids break down (5, 7, 16) have led to the suggestion that plastoglobuli are repositories for lipids resulting from lamellar breakdown. Studies of the lipid composition of plastoglobuli substantiate this suggestion. Lichtenthaler (18, 19, 20) and Barr and Arntzen (4) have shown a correlation between lipoquinone content and number of plastoglobuli in aging plastids. Additionally, Lichtenthaler (19, 20) has shown that plastoglobuli contain carotenoids. Senescing chloroplasts resemble developing chromoplasts, where disappearance of chloroplast lamellae is accompanied by an accumulation of pigmented lipid droplets (21, 33).

Plastosomes, a term used by Arnott and Harris (2) to describe vesicles derived from unique membrane discs in the stroma of develop-

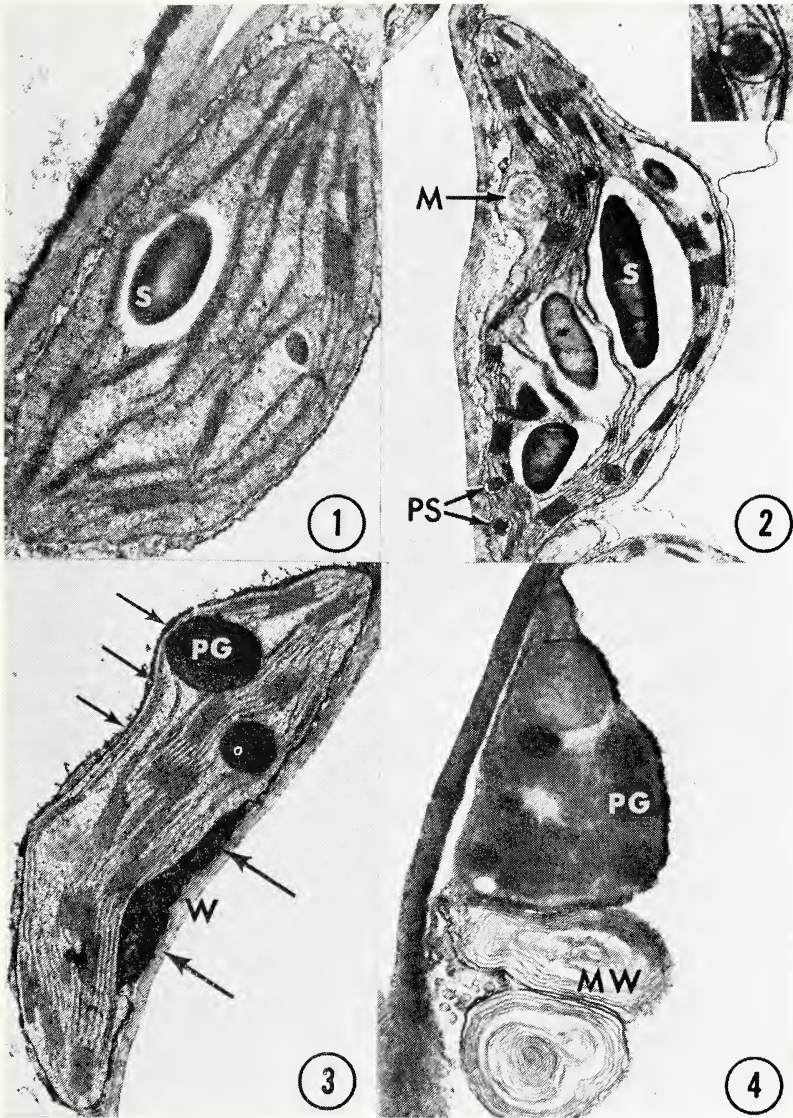


FIGURE 1. Chloroplasts of partially expanded leaves have elliptical profiles. The lamellar system is not elaborately developed and small starch grains (S) are present in the stroma. X 36,000.

FIGURE 2. In fully expanded leaves, the chloroplast profile is distorted by large starch grains (S). Cytoplasmic pockets in chloroplasts, though infrequent, may contain mitochondria (M). Plastosomes (PS) are common to chloroplasts at this stage of development. X 3,300. Inset shows detail of a plastosome. X 9,600.

FIGURE 3. Chloroplasts of yellow-green leaves contain large plastoglobuli (PG). Osmiophilic deposits occur in the cytoplasm adjacent to the plastid surface (small arrows) with massive deposits (large arrows) between the cell wall (W) and the plastid envelope. X 14,000.

FIGURE 4. Plastids of senescent, yellow tissue contain numerous plastoglobuli (PG). Cytoplasmic membrane whorls (MW) are common in cells at this stage of breakdown. X 18,500.



FIGURE 5. Degradative changes in senescent, yellow tissue include loss of the tonoplast and breakdown of the plastoglobuli (PG). Between the plastid (P) and the membrane whorl (MW) is a remnant of the cytoplasm (C). X 20,000.

FIGURE 6. All that remains in senescent cells when plastids are completely degraded is an irregular membrane along the cell wall (W) which sometimes appears single, sometimes double, and sometimes whorled. Osmiophilic deposits (D) are typical of this membrane. X 66,000.

FIGURE 7. Cells of fully senescent tissue are devoid of contents except for a membrane (arrows) along the cell wall (W), probably residual plasma membrane. X 6,800.

ing plastids, have only been described for tobacco. In agreement with Arnott and Harris (2), this study shows that plastosomes are an intermediate developmental stage preceding the appearance of plastoglobuli. Arnott and Harris (2) have shown a correlation between the appearance of plastosomes and a decrease in granal volume. Similar to plastoglobuli, plastosomes are partly lipid and may function in the isolation and/or release of metabolites during plastid development in tobacco (2).

In addition to lipid deposition within chloroplast suborganelles osmiophilic material accumulates in the cytoplasm adjacent to chloroplasts. Mittelheuser and Van Steveninck (24) reported formation of spherical lipid bodies in the cytoplasm of developing wheat leaves. These lipid bodies often distended the tonoplast and were occasionally observed between the chloroplast and plasma membrane. In contrast, cytoplasmic deposits in senescing tobacco leaves are amorphous masses adjacent to chloroplasts with massive deposits between the chloroplast and cell wall. Młodzianowski and Kwinthiewicz (25) observed osmiophilic deposits adjacent to mitochondria, as well as chloroplasts, in detached, aging leaves of kohlrabi. They attributed deposition of osmiophilic material on the surface of these organelles to the action of lipophanerase.

Roux and McHale (32) considered degradation of the tonoplast and plasma membrane an early occurrence in senescence of detached tomato leaves. However, the plasma membrane and tonoplast are persistent in other senescing tissues (5, 7, 9, 12, 24). As shown in this study, degenerative changes accompanying cell senescence are well underway before the breakdown of these membranes. Since the loss of the tonoplast occurs at the same time as breakdown of the plastoglobuli and plastid envelope, it is reasonable to suggest that release of vacuolar contents may be responsible for final degradation of aged chloroplasts.

A characteristic of tobacco cells in terminal stages of senescence is the presence of myelin-like membrane whorls. Membrane whorls associated with the plasma membrane (13, 23, 30), endoplasmic reticulum (29, 30), vacuole (6, 10, 14), and thylakoids of plastids (1) have been found in developing tissues. In tobacco, myelin-like membrane whorls are a consistent feature of senescent leaf tissue, however, their origin is not known. They may be of vacuolar and/or plasma membrane origin since these membranes are disappearing at the same time that the myelin-like whorls appear in aging cells. Other studies have shown that membrane whorls can arise from the tonoplast (14) and the plasma membrane (13).

In general, the sequence of events described for chloroplast senescence in tobacco resembles that reported for other species (8). In addition, our study shows the final degradative changes of aged chloroplasts that were not reported previously. The generality of these terminal stages among plant species remains to be determined.

Acknowledgements

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A Compilation of Plant Diseases and Disorders in Indiana—1975

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Abstract

A compilation of plant diseases and disorders which were diagnosed at the Plant Disease Diagnostic Clinic from October 1, 1974 through August 31, 1975, is presented. An early outbreak of ash anthracnose was the dominant shade tree disease; various root stress factors caused many disorder problems of shade trees, particularly sugar maple. Scab, fireblight, sooty blotch and flyspeck of apple and leaf curl, scab, and bacterial spot of peach were prevalent. Isolated outbreaks of peach stem pitting occurred in central and southern peach orchards.

Bacterial spot, bacterial wilt, bacterial canker, and *Alternaria* stem canker were identified on southern grown tomato transplants. Early blight and fruit anthracnose were serious problems on tomatoes. *Fusarium* wilt, bacterial wilt, and *Alternaria* leaf blight of cucurbits were repeatedly identified. Black dot root rot was widely distributed on potato.

Stewart's disease of corn was prevalent early in the season with less than expected late season development. Corn stalk and ear rots developed late in the season, especially in scattered areas of southern Indiana where drought stress occurred. Brown spot, bacterial blight, *Rhizoctonia* root rot, *Phytophthora* root rot, and pod and stem blight of soybeans were widespread. Scab, *Septoria* leaf blotch, and take-all of wheat were commonly reported. An alfalfa crown-root-rot complex was observed in several fields. Adverse environmental conditions affected corn and soybean yields in extreme northern and scattered areas of southern Indiana. Widespread herbicide damage occurred on soybeans in early June.

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Introduction

Plant diseases and disorders are diagnosed at the Purdue Plant Disease Diagnostic Clinic primarily as a service to county extension agents, but also to growers, homeowners, and others. Prompt, accurate, disease diagnosis along with current, safe, and effective control suggestions play a vital role in Indiana agriculture. This compilation will serve as a record of the diseases and disorders diagnosed in Indiana from October 1, 1974 to August 31, 1975. When compared with similar compilations published previously (2, 4), and anticipated future compilations, it is possible to determine trends in the increase, decrease, or stability of Indiana plant diseases and disorders. This information can be used by agricultural research, extension, grower, and consultant personnel to direct problem oriented research activities, plan effective control programs, and choose plant varieties best able to resist prevalent diseases.

Methods and Materials

Plant specimens with symptoms of plant diseases or disorders were collected by county extension agents, growers, agribusiness personnel, and homeowners, and forwarded to the Purdue Plant Disease Diagnostic Clinic for diagnosis. Symptoms and signs on submitted specimens were categorized and recorded upon receipt. If

necessary, infected plant tissue was plated on selected media to facilitate isolation and identification of the causal agent. After the disease or disorder was identified, appropriate control measures were prescribed.

Results and Discussion

A list of specimens examined in the clinic during the past year is given in Table 1. Disease name, causal agent, and the frequency of diagnosis are given for each of the plant groups in tables 2-9.

The frequency of diagnoses for diseases and disorders should not always be construed as an indication of severity within Indiana, as many diseases and disorders are easily identified in the field and are not submitted to the Plant Disease Diagnostic Clinic.

TABLE 1. *Plant specimens examined in the Purdue Plant Disease Diagnostic Clinic from October 1, 1974 through August 31, 1975.*

Plant Group	Number of Specimens
Corn -----	86
Flowers -----	22
Forage Grasses and Legume -----	30
House Plants -----	41
Ornamentals -----	140
Plant Identification -----	7
Small Fruit -----	53
Small Grain -----	54
Soybeans -----	94
Tree Fruit -----	100
Trees—Shade and Ornamental -----	352
Turf -----	26
Vegetables -----	320
Miscellaneous -----	3
Total -----	1328

Shade and Ornamental Trees

Diseases: Anthracnose was the major disease of shade trees (Table 2). Although the occurrence of anthracnose on maple, oak, and sycamore was less than in 1974 (2), an outbreak of anthracnose on ash in southern Indiana resulted in severe defoliation of some areas. Verticillium wilt, second in frequency of diagnosis, was most prevalent on maples. Regarding major diseases of ornamental trees, Diplodia tip blight was prevalent on established plantings of Austrian and red pine, Cytospora canker was commonly identified on spruce trees subjected to stress conditions, and Lophodermium needle cast was largely confined to Christmas tree plantations.

Disorders: Shade tree disorders continue to outnumber diseases. Leaf scorch, primarily due to a combination of heat, wind and drought, was a predominant disorder, as in previous years (2, 4). Decline of maples and other trees was prevalent throughout Indiana. Decline, a gradual die-back of shade trees which eventually results in death, in some instances has been associated with stress factors such as grade

changes, girdling roots, and soil compaction. For the most part, however, the cause(s) of stress are not well understood.

Ornamentals

Diseases: Phomopsis tip blight of juniper, which causes a die-back of new terminal growth and in some cases death of young plants, was the most frequently observed ornamental disease (Table 3). Phytophthora root rot was frequently associated with a die-back of Taxus (Yew). Poorly drained planting sites and heavy waterlogged soil apparently contributed to the incidence of Taxus die-back. Among the many ornamentals infected with powdery mildew, Euonymus and lilac were particularly hard hit.

Disorders: Winter desiccation of evergreens, scorch, and injury from herbicide drift were the most frequently identified disorders of ornamentals.

TABLE 2. *Diseases and disorders of shade and ornamental trees in Indiana—1975¹*

Acer (Maple)

Diseases: anthracnose (*Gloeosporium apocryptum*)—7; wilt (*Verticillium albo-atrum*)—7; purple eye leaf spot (*Phyllosticta minima*)—3; leaf spot (unidentified fungi)—2.

Disorders: scorch (heat, wind and drought)—32; decline (various stress factors)—26; frost injury (late spring frost)—2; herbicide injury (spray drift)—1; air pollution injury—1.

Betula (Birch)

Disease: canker (*Melanconium betulinum*)—2.

Disorders: decline (various stress factors)—3.

Cercis (Redbud)

Diseases: canker (*Botryosphaeria dothidea*)—1; leaf spot (unidentified fungus)—1.

Disorders: scorch (inadequate root development)—3; herbicide injury (spray drift)—3; decline (various stress factors)—3; bark splitting (temperature extremes)—1.

Cornus (Dogwood)

Disease: spot anthracnose (*Elsinoe corni*)—1.

Disorders: scorch (heat, wind and drought)—3; chlorosis (iron deficiency)—1.

Cotinus (Smoke-Tree)

Disease: wilt (*Verticillium albo-atrum*)—1.

Crataegus (Hawthorn)

Diseases: cedar-quince rust (*Gymnosporangium clavipes*)—2; canker (cause unidentified)—2; fire blight (*Erwinia amylovora*)—1; leaf blight (*Fabracea maculata*)—1.

Cydonia (Quince)

Disease: leaf spot (*Fabracea maculata*)—1.

Elacagnus (Russian-Olive)

Disease: canker (*Fusicoccum elacagni*)—2.

Disorder: leaf yellowing (nutritional disorder)—1.

Fraxinus (Ash)

Disease: anthracnose (*Gloeosporium aridum*)—9.

Disorders: decline (various stress factors plus drought)—3; scorch (heat, wind and drought)—1.

Gleditsia (Honey Locust)

Disorders: decline (various stress factors)—2; herbicide injury (spray drift)—1.

Juglans (Walnut)

Disease: anthracnose (*Gnomonia leptostyla*)—1.

Disorders: scorch (heat, wind and drought)—1; die-back (root injury)—1.

TABLE 2. (cont.)

<i>Koelreuteria</i> (Golden Rain Tree)	
Disorder: decline (various stress factors)—2.	
<i>Liquidambar</i> (Sweetgum)	
Disorders: scorch (heat, wind and drought)—2; chemical injury (spray drift)—1.	
<i>Liriodendron</i> (Tulip Tree)	
Disorders: decline (various stress factors)—7; leaf yellowing (natural)—6; leaf scorch (heat, wind and drought)—3; sooty mold (insect honeydew secretions)—1.	
<i>Magnolia</i> (Magnolia)	
Disease: leaf spot (<i>Phyllosticta cookei</i>)—1.	
Disorders: winter desiccation—3; air pollution—1.	
<i>Malus</i> (Crabapple)	
Diseases: scab (<i>Venturia inaequalis</i>)—4; powdery mildew (<i>Podosphaera leucotricha</i>)—2; fire blight (<i>Erwinia amylovora</i>)—2; cedar-apple rust (<i>Gymnosporangium juniperi-virginianae</i>)—1.	
Disorders: die-back (rot injury)—2; leaf yellowing (nitrogen deficiency)—1.	
<i>Picea</i> (Spruce)	
Disease: canker (<i>Cytospora kunzei</i>)—4.	
Disorders: decline (various stress factors)—3; winter desiccation—1; herbicide injury (spray drift)—1.	
<i>Pinus</i> (Pine)	
Diseases: tip blight (<i>Diplodia pinca</i>)—4; needle cast (<i>Lophodermium pinastri</i>)—3; needle blight (<i>Dothistroma pini</i>)—2; needle rust (<i>Colosporium asterum</i>)—1.	
Disorders: decline (poor site location plus stress factors)—13; winter desiccation—4; air pollution injury—2; needle tip burn (heat, wind and drought)—2; sooty mold (insect honeydew secretions)—1.	
<i>Populus</i> (Poplar, Aspen, Cottonwood)	
Disease: aspen leaf spot (<i>Marssonina populi</i>)—1.	
Disorder: scorch (heat, wind and drought)—1.	
<i>Quercus</i> (Oak)	
Diseases: oak wilt (<i>Cercosyctis fagaccarum</i>)—5; leaf spot (<i>Actinopelte dryina</i>)—3; slime flux (bacterial infection)—3; canker (<i>Dothiorella quercina</i>)—2.	
Disorders: chlorosis of pin oak (iron deficiency)—10; scorch (heat, wind and drought)—8; decline (various stress factors)—3; herbicide injury (spray drift)—3.	
<i>Salix</i> (Willow)	
Disorder: scorch (heat, wind and drought)—2.	
<i>Sorbus</i> (Mountain Ash)	
Disorders: scorch (heat, wind and drought)—2; decline (various stress factors)—2.	
<i>Tilia</i> (Linden)	
Disorders: die-back (root injury)—1; trunk sunscald (winter temperature extremes)—1; herbicide injury (spray drift)—1.	
<i>Tsuga</i> (Hemlock)	
Disease: canker (<i>Cytospora kunzei</i>)—1.	
Disorder: winter desiccation—2.	
<i>Ulmus</i> (Elm)	
Diseases: dutch elm disease (<i>Ceratocystis ulmi</i>)—2; leaf spot (unidentified fungus)—1.	

¹ Diseases listed for each plant species in order of frequency. Listing does not include plant species which had only a single occurrence of a disorder.

Tree Fruits

Diseases: Fireblight, apple scab, sooty blotch, and flyspeck were the most commonly identified apple diseases (Table 4). Weather conditions at bloom and throughout the early part of the growing season were favorable for fireblight development. Susceptible apple cultivars

were heavily infected in many orchards throughout the state. Apple scab, an important disease every year, again was present throughout Indiana. An apparent increase in sooty blotch and flyspeck of apple fruit over last year was attributed to weather conditions favorable for disease development which occurred late in the growing season when growers had relaxed their fungicide spray programs. Frequently observed peach diseases included peach leaf curl (confined mainly to backyard growers), bacterial spot, and scab. Of particular interest was the first confirmed identification of peach stem pitting in commercial peach orchards in middle and southern Indiana. Studies on the etiology and control of this disease are in progress.

TABLE 3. *Diseases and disorders of ornamentals in Indiana—1975¹*

<i>Ajuga</i> (Bugle-Weed)	
Disease: crown rot (<i>Sclerotium delphinii</i>)—1.	
<i>Althaea</i> (Hollyhock)	
Disease: rust (<i>Puccinia malvacearum</i>)—3.	
<i>Aster</i> (Aster)	
Disease: leaf spot (<i>Alternaria</i> sp.)—2.	
<i>Dahlia</i> (Dahlia)	
Disease: botrytis blight (<i>Botrytis cinerea</i>)—1.	
<i>Euonymus</i> (Euonymus)	
Diseases: powdery mildew (<i>Microspora alni</i>)—3; crown gall (<i>Agrobacterium tumefaciens</i>)—3; leaf spot (<i>Alternaria</i> sp.)—1.	
Disorders: die-back (root stress)—3; scorch (heat, wind and drought)—1; late frost injury—1.	
<i>Forsythia</i> (Golden Bells)	
Disorder: scorch (heat, wind and drought)—1.	
<i>Gladiolus</i> (Gladiolus)	
Diseases: bacterial leaf blight (<i>Xanthomonas gummosus</i>)—1; Fusarium basal dry-rot (<i>Fusarium oxysporum</i> f. <i>gladioli</i>)—1.	
<i>Ilex</i> (Holly)	
Disease: leaf spot (<i>Phyllosticta</i> sp.)—1.	
Disorders: spine spot (spine punctures)—5; winter desiccation—2; die-back (improper site location)—1.	
<i>Juniperus</i> (Juniper)	
Diseases: twig blight (<i>Phomopsis juniperovora</i>)—10; cedar-apple rust (<i>Gymnosporangium juniperi-virginianae</i>)—3.	
Disorders: die-back (root problem)—1; winter desiccation—1.	
<i>Ligustrum</i> (Privet)	
Disorders: premature fall coloration (weather related)—2; die-back (root injury)—2.	
<i>Lonicera</i> (Honeysuckle)	
Disorders: die-back (root injury)—1; scorch (heat, wind and drought)—1.	
<i>Pachysandra</i> (Pachysandra)	
Disease: leaf blight (<i>Volutella pachysandrae</i>)—2.	
<i>Paeonia</i> (Peony)	
Diseases: botrytis blight (<i>Botrytis cinerea</i>)—2; red spot (<i>Cladosporium paeoniae</i>)—1; phytophthora blight (<i>Phytophthora cactorum</i>)—1.	
<i>Petunia</i> (Petunia)	
Disease: dodder (<i>Cuscuta</i> sp.)—1.	
<i>Pelargonium</i> (Geranium)	
Diseases: bacterial blight (<i>Xanthomonas pelargonii</i>)—4; blackleg (<i>Pythium</i> sp.)—1; botrytis blight (<i>Botrytis cinerea</i>)—1; rust (<i>Puccinia pelargonii-zonalis</i>)—1.	
Disorder: leaf yellowing (nutritional disorder)—1.	

TABLE 3. (cont.)

<i>Philadelphus</i> (Mock-Orange)	
Disease:	canker (<i>Nectria cinnabarina</i>)—1.
Disorder:	die-back (root injury)—1.
<i>Pyracantha</i> (Firethorn)	
Disease:	scab (<i>Fusicladium pyracanthae</i>)—4.
Disorder:	root rot (waterlogged soil)—1.
<i>Rhododendron</i> (Azalea and Rhododendron)	
Diseases:	die-back (<i>Phytophthora cactorum</i>)—2; crown rot (<i>Phytophthora</i> sp.)—1; leaf spot (unidentified fungus)—1; leaf gall (<i>Exobasidium vaccinii</i>)—1.
Disorder:	leaf chlorosis (high soil pH)—2.
<i>Rosa</i> (Rose)	
Diseases:	black spot (<i>Diplocarpon rosae</i>)—2; botrytis blight (<i>Botrytis cinerea</i>)—2; canker (<i>Phoma</i> sp.)—1; common stem canker (<i>Leptosphaeria coniothyrium</i>) —1; dodder (<i>Cuscuta</i> sp.)—1.
Disorders:	herbicide injury (spray drift)—2; root rot (unidentified causes)—2; leaf chlorosis (nutritional disorder)—1.
<i>Syringa</i> (Lilac)	
Diseases:	powdery mildew (<i>Microsphaera alni</i>)—3.
Disorders:	die-back (unidentified causes)—2; scorch (heat, wind and drought)—1.
<i>Taxus</i> (Yew)	
Disease:	crown rot-root rot (<i>Phytophthora</i> sp.)—6.
Disorders:	root rot (waterlogged soil)—3; herbicide injury—3; frost injury—2.
<i>Thuja</i> (Arbor-Vitae)	
Disease:	die-back (lesion nematode— <i>Pratylenchus</i> sp.)—1.
Disorders:	fall needle browning (natural)—3; winter desiccation—2; brown foliage (dog damage)—1.
<i>Tulipa</i> (Tulip)	
Disease:	botrytis blight (<i>Botrytis tulipae</i>)—2.
<i>Viburnum</i> (Viburnum)	
Disease:	leaf spot (unidentified fungus)—1.
Disorder:	decline (various stress factors)—2.

¹ Disease listed for each plant species in order of frequency. Listing does not include plant species which had only a single occurrence of a disorder.

Small Fruit

Diseases and Disorders: Raspberry anthracnose, black rot of grape, and black root rot of strawberry were the most prevalent diseases of small fruit (Table 5). No major diseases or disorders were present in Indiana during the past year.

TABLE 4. Disease and disorders of fruit trees in Indiana—1975¹

<i>Malus sylvestris</i> (Apple)	
Diseases:	fire blight (<i>Erwinia amylovora</i>)—5; scab (<i>Venturia inaequalis</i>)—4; sooty blotch (<i>Gloeodes pomigena</i>)—4; fly speck (<i>Microthyriclla rubi</i>)—4; canker (unidentified causes)—3; powdery mildew (<i>Podosphaera leucotricha</i>)—2; crown rot (<i>Phytophthora cactorum</i>)—2; black rot (<i>Physalospora obtusa</i>) —2.
Disorders:	chemical injury (improper use)—3; herbicide injury (spray drift)—2; measles (manganese toxicity)—1.
<i>Prunus americana</i> (Plum)	
Diseases:	black knot (<i>Dibotryon morbosum</i>)—5; brown rot (<i>Sclerotinia fructicola</i>)— 3; crown gall (<i>Agrobacterium tumefaciens</i>)—1.
Disorder:	chemical injury (improper use)—1.

TABLE 4. (cont.)

Prunus avium (Cherry)

Diseases: brown rot (*Sclerotinia fructicola*)—4; leaf spot (*Coccomyces hiemalis*)—1; powdery mildew (*Podosphaera oxyacanthae*)—1; black knot (*Dibotryon morbosum*)—1; bacterial canker (*Xanthomonas pruni*)—1.

Disorders: die-back (various stress factors)—4; scorch (heat, wind and drought)—3; herbicide injury (spray drift)—2; leaf chlorosis (nutritional disorder)—1.

Prunus persica (Peach)

Diseases: leaf curl (*Taphrina deformans*)—7; bacterial spot (*Xanthomonas pruni*)—5; scab (*Cladosporium carpophilum*)—3; stem pitting (soil-borne virus)—3; crown gall (*Agrobacterium tumefaciens*)—1; brown rot (*Sclerotinia fructicola*)—1; perennial canker (*Leucostoma cincta*)—1.

Disorders: root rot (waterlogged soil)—3; herbicide injury (spray drift)—3; winter injury—1; internal fruit browning (unknown cause)—1.

Pyrus communis (Pear)

Diseases: bitter rot (*Glomerella cingulata*)—2; leaf blight (*Fabreaa maculatum*)—1.

Disorders: decline (various stress factors)—2; scorch (heat, wind and drought)—1.

¹ Disease listed for each plant species. Common name, scientific name, and frequency of occurrence are given for each disease listed.

Houseplants

Diseases and Disorders: A three-fold increase in specimens of houseplants received as compared with those of 1974, reflected the increased popularity of houseplants (Table 6). Schefflera was the most commonly submitted foliage plant. Most specimens of houseplants were characterized by a general root decay which was primarily due to overwatering or poor drainage.

TABLE 5. Diseases and disorders of small fruits in Indiana—1975¹*Fragaria grandiflora* (Strawberry)

Diseases: black root rot (specific pathogen(s) not known)—5; june yellows (cause unknown)—2; gray mold (*Botrytis cinerea*)—2; stem end rot (*Gnomonia fructicola*)—2; leaf blight (*Dendrophoma obscurans*)—1; wilt (*Verticillium albo-atrum*)—1; leaf scorch (*Diplocarpon earliana*)—1; red stele (*Phytophthora fragariae*)—1.

Rubus (Blackberry)

Diseases: sterility (virus)—2; orange rust (*Gymnoconia peckiana*)—1.

Rubus (Raspberry)

Diseases: anthracnose (*Elsinoe veneta*)—4; cane blight (*Phylospora obtusa*)—1; wilt (*Verticillium albo-atrum*)—1; crumbly berry (tomato ringspot virus)—1.

Disorders: herbicide injury (spray drift)—1; cold injury—1.

Ribes (Gooseberry)

Disease: 'American' powdery mildew (*Sphaerotheca mors-uvae*)—2.

Vaccinium (Blueberry)

Diseases: blight (*Botrytis cinerea*)—1; twig canker (*Phomopsis vaccinii*)—1.

Vitis (Grape)

Diseases: black rot (*Guignardia bidwellii*)—4; powdery mildew (*Uncinula necator*)—2; crown gall (*Agrobacterium tumefaciens*)—1.

Disorders: herbicide injury (spray drift)—3; chemical injury (improper use)—2; die-back (root injury)—1.

¹ Diseases listed for each plant species in order of frequency.

TABLE 6. *Diseases and disorders of houseplants in Indiana—1975*¹*Asparagus* (Asparagus-Fern)

Disorder: leaf yellowing (high temperature plus low humidity)—2.

Begonia (Begonia)Diseases: bacterial blight (*Xanthomonas begoniae*)—2; root knot nematode (*Meloidogyne* sp.)—1.*Brassaia* (Shefflera)

Disorders: root rot (poor drainage plus overwatering)—8; chemical injury (spray drift)—1.

Chlorophytum (Spider Plant)

Disorder: tip burn (fluoride toxicity)—3.

Citrus (Panama Orange)

Disorder: scorch (high temperature plus low humidity)—1.

Crassula (Jade Plant)

Disorder: root rot (overwatering)—1.

Dieffenbachia (Dumb Cane)

Disorder: lower leaf yellowing (natural)—2.

Dracaena (Corn Plant)

Disorder: tip burn (salt accumulation)—2.

Ficus (India Rubber Plant)

Disorders: root rot (poor drainage plus overwatering)—2; stem canker (cause unknown)—1.

Gardenia (Gardenia)

Disease: powery mildew (not identified)—1.

Gynura (Velvet Plant)

Disorder: poor root growth (poor growing conditions)—2.

Lilium (Lily)

Disease: root and bulb rot (unknown complex of fungi, bacteria and nematodes)—3.

Monstera (Split-leaf Philodendron)

Disease: leaf mosaic (unidentified virus)—1.

Nephrolepis (Fern)

Disorder: die-back (low humidity)—3.

Orchidaceae (Orchid)Disease: bacterial soft rot (*Erwinia carotovora*)—1.*Peperomia* (Variegated Peperomia)Disease: root rot (*Phytophthora palmivora*)—1.

Disorder: leaf tip necrosis (chemical toxicity)—1.

Persea (Avocado)

Disorder: root rot (poor drainage plus overwatering)—1.

Saintpaulia (African Violet)

Disorder: leaf ringspot (cold water on leaves)—2.

¹ Diseases listed for each plant species in order of frequency.**Turfgrass**

Diseases: Turfgrass diseases were more prevalent in 1975 than in 1974 (2) (Table 7). Helminthosporium leaf spot was, by far, the predominant foliar disease of bluegrass.

Vegetables

Diseases: Several infectious diseases appeared to be carried into Indiana from southern states on infected tomato transplants (Table 8). These diseases included bacterial spot, bacterial canker, bacterial wilt, Alternaria stem canker, and nailhead spot. Prevalent mid and late season tomato diseases included Fusarium wilt, early blight, Septoria leaf blight, and fruit anthracnose. Early blight was responsible for severe defoliation of extensive commercial tomato acreage in late

August and early September. Important diseases of cucurbits included bacterial wilt, *Alternaria* leaf spot, and *Fusarium* wilt. A mild winter which favored the survival of cucumber beetles, a vector of the bacterial wilt pathogen, appeared to be a major factor in an early season outbreak of bacterial wilt on muskmelon. Although *Alternaria* leaf spot of muskmelon was frequently identified, crop injury was minimized with periodic fungicide applications. Black dot root rot of potato caused by *Colletotrichum coccodes* was in the majority of potato fields visited during 1975 and on several submitted samples of potato.

Disorders: Chemical injury was identified on specimens of most vegetable crops. Causes of chemical injury included herbicide drift, application of incompatible tank mixes, and application of certain pesticides during hot humid periods when phytotoxicity was most likely to occur.

TABLE 7. *Diseases and disorders of turf grasses in Indiana—1975¹*

<i>Poa pratensis</i> (Kentucky Blue Grass)	
Diseases:	leaf spot and melting out (<i>Helminthosporium</i> spp.)—14; <i>Fusarium</i> blight (<i>Fusarium</i> spp.)—2; stripe smut (<i>Ustilago striiformis</i>)—1.
Disorders:	slime mold (<i>Physarum cinereum</i>)—1; environmental—2; chemical—1.
<i>Agrostis</i> spp. (Bent Grass)	
Disease:	red leaf (<i>Helminthosporium erythrosphyllum</i>)—3.
<i>Festuca</i> spp. (Fescue)	
Diseases:	red thread (<i>Corticium fuciforme</i>)—1; <i>Pythium</i> blight (<i>Pythium ultimum</i>)—1.

¹ Diseases listed for each crop species in order of frequency.

TABLE 8. *Diseases and disorders of vegetable crops in Indiana—1975¹*

<i>Allium cepa</i> (Onion)	
Diseases:	basal bulb rot (<i>Fusarium</i> spp.)—4; black mold (<i>Aspergillus niger</i>)—2; leaf blight (<i>Botrytis cinerea</i>)—2; purple blotch (<i>Alternaria porri</i>)—1; soft rot (unidentified bacterial pathogen)—1.
<i>Beta vulgaris</i> (Beet)	
Disorder:	chemical injury (spray drift)—1.
<i>Brassica juncea</i> var. <i>crispifolia</i> (Mustard)	
Disease:	leaf spot (<i>Cercospora brassiciola</i>)—1.
<i>Brassica oleracea</i> var. <i>botrytis</i> (Broccoli and Cauliflower)	
Disorders:	cold weather injury—1; seedling die-back (soluble salt toxicity)—1.
<i>Brassica oleracea</i> var. <i>capitata</i> (Cabbage)	
Diseases:	wire-stem (<i>Rhizoctonia solani</i>)—3; black rot (<i>Xanthomonas campestris</i>)—2; clubroot (<i>Plasmodiophora brassicae</i>)—1; yellows (<i>Fusarium oxysporum</i> f. <i>conglutinans</i>)—1.
Disorder:	chemical injury (spray drift)—4.
<i>Brassica rapa</i> (Turnip)	
Disorder:	leaf spot (chemical injury)—1.
<i>Capsicum frutescens</i> (Pepper)	
Disorders:	air pollution injury—1; chemical injury—1; hail injury—1; wind injury—1.
<i>Citrullus vulgaris</i> (Watermelon)	
Diseases:	<i>Fusarium</i> wilt (<i>Fusarium oxysporum</i> f. <i>niveum</i>)—4; gummy stem blight (<i>Mycosphaerella melonis</i>)—1; root knot nematode (<i>Mcloidogyne</i> sp.)—1.
Disorders:	chemical injury—1; environmental stress—2; insect feeding injury—1; soluble salt toxicity—1; wind injury—1.

TABLE 8. (cont.)

Cucumis melo var. *reticulatus* (Muskmelon)

Diseases: leaf blight (*Alternaria cucumerina*)—8; bacterial wilt (*Erwinia tracheiphila*)—6; Fusarium wilt (*Fusarium oxysporum* f. *melonis*)—2; downy mildew (*Pseudoperonospora cubensis*)—2; powdery mildew (*Erysiphe cichoracearum*)—2; gummy stem blight (*Mycosphaerella melonis*)—1.

Disorders: leaf spot (chemical injury)—10; seedling die-back (soluble salt toxicity)—1.

Cucumis sativus (Cucumber)

Disease: bacterial wilt (*Erwinia tracheiphila*)—2.

Disorders: leaf spot (chemical injury)—4; insect feeding injury—1.

Cucurbita spp. (Pumpkin, Squash)

Disease: black rot (*Mycosphaerella melonis*)—1.

Disorders: chemical injury—5; insect feeding injury—2; environmental stress—1.

Ipomoea batatas (Sweet Potato)

Diseases: scurf (*Monilochaetes infusans*)—2; charcoal rot (*Macrophomina phaseoli*)—1; storage root rot (*Fusarium oxysporum*)—1.

Lycopersicon esculentum (Tomato)

Disease: early blight—stem and foliage lesions (*Alternaria solani*)—15; bacterial spot (*Xanthomonas vesicatoria*)—12; Septoria leaf spot (*Septoria lycopersici*)—6; Fusarium wilt (*Fusarium oxysporum* f. *lycopersici*)—6; bacterial wilt (*Pseudomonas solanacearum*)—3; bacterial canker (*Corynebacterium michiganense*)—2; Verticillium wilt (*Verticillium dahliae*)—2; damping-off (*Pythium* sp.)—1; ghost spot (*Botrytis cinerea*)—1; nailhead spot (*Alternaria tomato*)—1; soft rot of transplants (unidentified bacterial pathogen)—1.

Disorders: chemical injury (herbicide (drift))—15; insect feeding injury—7; nutrient deficiency—5; high temperature injury—4; physiological leaf roll—4; soluble salt toxicity—4; blossom end rot (insufficient water)—2; walnut wilt (toxic walnut tree excretions)—2; blotchy fruit ripening—1; drought stress—1; fruit rot (over-ripe fruit)—1.

Pastinaca sativa (Parsnip)

Disease: soft rot (unidentified bacterial pathogen)—1.

Phaseolus vulgaris (Snap Bean)

Diseases: Fusarium root rot (*Fusarium* sp.)—4; stem canker (*Rhizoctonia solani*)—2; common bacterial blight (*Xanthomonas phaseoli*)—1.

Disorders: chemical injury (herbicide drift)—12; insect feeding injury—10; leaf necrosis (sunscald)—7; soluble salt toxicity—1.

Pisum sativum (Pea)

Disease: Fusarium wilt (*Fusarium oxysporum* f. *pisi*)—3.

Rheum officinale (Rhubarb)

Diseases: anthracnose (*Colletotrichum crumpens*)—3; *Alternaria* leaf, stalk spot (*Alternaria* sp.)—1; *Ascochyta* leaf spot (*Ascochyta rhei*)—1.

Disorders: hail injury—1; sunscald—1.

Solanum tuberosum (Potato)

Diseases: black dot root rot (*Colletotrichum coccodes*)—6; early blight (*Alternaria solani*)—3; common scab (*Streptomyces scabies*)—2; late blight (*Phytophthora infestans*)—1; silver scurf (*Spongylocadium atrovirens*)—1; stem rot (*Botrytis cinerea*)—1; tuber dry rot (*Fusarium* sp.)—1; Verticillium wilt (*Verticillium dahliae*)—1.

Disorders: chemical injury (herbicide drift)—2; black heart (physiological)—1; hollow heart (physiological)—1; secondary tuber formation (physiological)—1.

Spinacia oleracea (Spinach)

Disease: downy mildew (*Peronospora* sp.)—1.

Disorder: chemical injury (herbicide drift)—1.

Zea mays var. *saccharata* (Sweet Corn)

Diseases: anthracnose (*Colletotrichum graminicola*)—1; bacterial leaf blight (*Xanthomonas stewartii*)—1; northern leaf blight (*Helminthosporium turcicum*)—1; smut (*Ustilago maydis*); Stewart's wilt (*Xanthomonas stewartii*)—1.

Disorders: chemical injury—4; insect feeding injury—2.

¹ Diseases listed for each crop species in order of frequency.

Soybeans

Diseases: Brown spot and bacterial leaf blight were common early season diseases. *Phytophthora* and *Rhizoctonia* root rots were also widespread (Table 9). Races 1, 3, 4, 5, and 6 of *Phytophthora megasperma* var *sojae* have now been identified in the state (1). The new races 3, 4, 5, and 6 are currently confined to six northwestern Indiana counties. Pod and stem blight was extremely severe on early planted Group II maturity soybeans. Later maturing varieties were relatively free of the disease. Purple seed stain was widespread but not damaging. Charcoal rot caused yield losses for the first time in several years in a few northwestern Indiana fields.

Disorders: Chemical injury was widespread throughout the state early in the season. Damage was severe in individual fields and growers were forced to replant some acreage.

TABLE 9. Diseases and disorders of agronomic crops in Indiana—1975¹*Zea mays* (Field Corn)

Diseases: Stewart's disease (*Erwinia stewartii*)—18; stalk rots (*Gibberella zeae*—8; *Diplodia zeae*—5; *Colletotrichum graminicola*—4; *Nigrospora oryzae*—2)—19; ear rots (*Gibberella zeae*—6; *Fusarium moniliforme*—4; *Diplodia zeae*—3; *Cladosporium herbarum*—1; *Aspergillus fumigatus*—1)—15; viruses (Maize dwarf mosaic virus—3; Maize chlorotic dwarf virus—1)—4; anthracnose (*Colletotrichum graminicola*)—2; seedling blight (*Diplodia zeae*)—2; root rot (*Rhizoctonia solani*)—1; rust (*Puccinia sorghi*)—1.

Disorders: erratic emergence and poor root development (environmental)—20; chemical damage—8.

Glycine max (Soybeans)

Diseases: root rots (*Phytophthora megasperma* var. *sojae*—10; *Rhizoctonia solani*—5)—15; brown spot (*Septoria glycines*)—14; downy mildew (*Percnospora manschurica*)—4; seedling blights (*Diaporthe phaseolorum*—2; *Pythium* spp.—2)—4; bacterial blight (*Pseudomonas glycines*)—3; charcoal rot (*Macrophomina phaseoli*)—3; pod and stem blight (*Diaporthe phaseolorum*)—3; brown stem rot (*Cephalosporium gregatum*)—2; frogeye leaf spot (*Cercospora sojae*)—2; powdery mildew (*Erysiphe polygoni*)—1.

Disorder: chemical damage—43.

Triticum aestivum (Wheat)

Diseases: Take-all (*Ophiobolus graminis*)—11; septoria leaf blotch (*Septoria tritici*)—7; fusarium root rot (*Fusarium* spp.)—3; scab (*Gibberella zeae*)—3; septoria glume blotch (*Septoria nodorum*)—3; virus (barley yellow dwarf virus—1; wheat spindle streak virus—1)—2.

Disorder: heaving (environmental conditions)—14.

Avena sativa (Oats)

Diseases: virus (barley dwarf virus)—3; halo blight (*Pseudomonas coronafaciens*)—2; loose smut (*Ustilago avenae*)—1.

Disorder: chemical damage—3.

Hordeum vulgare (Barley)

Diseases: scald (*Rhynchosporium secalis*)—2; virus (barley yellow dwarf virus)—1.

Medicago sativa (Alfalfa)

Diseases: root rot (*Phytophthora cactorum*)—9; bacterial wilt (*Corynebacterium insidiosum*)—6; common leaf spot (*Pseudopeziza medicaginis*)—4; sclerotinia crown and stem rot (*Sclerotinia trifoliorum*)—3; black stem (*Ascochyta imperfecta*)—1; fusarium root rot (*Fusarium* sp.)—1; leaf spot (*Stemphylium* sp.)—1.

Disorder: nutritional—5.

¹ Diseases listed for each crop species in order of frequency.

Corn

Diseases: Infectious diseases of corn caused minimal concern during the early part of the growing season (Table 9). Stewart's disease and various other bacterial leaf blights were prevalent in many fields, but these diseases failed to develop to damaging proportions. In early August, *Gibberella* and *Nigrospora* stalk rots began to appear in southern Indiana. The damage was most severe in southern Indiana areas affected by drought. Severe lodging occurred in some individual fields. While stalk rots were most severe in the southern half of the state, these diseases appeared in many fields throughout the state. Ear rots were prevalent throughout the state, with Gib ear rot being most prevalent in the northern half of the state. Gib ear rot was responsible for hog refusal in localized areas with Howard and Cass counties being most severe. Maize Dwarf Mosaic and Maize Chlorotic Dwarf virus diseases were damaging in southern Indiana fields infested with Johnsongrass and planted to susceptible corn hybrids. Virus symptoms were visible on most Johnsongrass plants observed throughout southern Indiana.

Severe stalk rot caused by *Colletotrichum graminicola* (anthracnose) was observed for the first time in Indiana in 1975. This organism was first identified in Indiana on sweet corn in 1972 (3). At that time the organism was identified on dent corn, but only as a minor foliar problem. During 1974 and again in 1975, the organism was identified late in the season as the incitant of a stalk rot on the upper part of the stalk. No losses were encountered as a result of the upper stalk rots. However, in late August 1975, a single field in northcentral Indiana was 60% lodged from lower stalk infections. *C. graminicola* has since been identified from below the ear parts of corn stalks in numerous Indiana fields. While losses from this disease will be minimal in 1975, it is a disease that must be closely watched for development in future years.

Small Grains

Diseases: Take-all was widespread in Indiana wheat fields again in 1975 (Table 9), but losses were not as great as in 1974. Scab was widespread throughout the state and caused some yield reductions in individual fields. Septoria leaf blotch appeared in many fields, but disease development was relatively late and disease losses were minimal. Barley Yellow Dwarf virus was prevalent in southern Indiana oat and barley fields, but yield losses were not as great as in 1974. Scald was again severe in many southern Indiana barley fields.

Alfalfa

Diseases: Bacterial wilt and root rots caused by *Phytophthora* sp. or *Fusarium* sp., resulted in severe stand losses in numerous fields throughout the state (Table 9).

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CELL BIOLOGY

Chairman: PAUL MAHLBERG, Department of Plant Sciences,
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LEE F. ELLIS, Lilly Research Labs.,
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ABSTRACTS

Agglutination of Protoplasts from Crown Gall Tumors of Bean Leaves. GEORGEANNE HARRIS, C. MAYES, CAROL L. RICHARDSON, and D. JAMES MORRÉ, Purdue University, West Lafayette, Indiana 47907.—Protoplasts from normal bean leaf tissue and crown gall tumor tissue induced by *Agrobacterium tumefaciens* were compared. The tumor tissue shows increased tendency toward agglutination both with and without addition of concanavalin A. The results suggest an alteration in the properties of surface membranes in a plant tumor system.

Glycolipids of Plant Tumors. JOHN F. QUINN, WILLIAM J. HURKMAN, CAROL L. RICHARDSON, and D. JAMES MORRÉ, Purdue University, West Lafayette, Indiana 47907.—Total glycolipids and glycolipids from membrane fractions of kohlrabi were analyzed. The total pattern of normal tissue was compared with that of tumor tissue induced by inoculation with *Agrobacterium tumefaciens*. Results indicate that plasma membranes of kohlrabi have a unique pattern of glycolipids and that membrane glycolipids of control and tumor tissues are similar.

Ultrastructural Characterization of Membrane Fractions from the Fungus *Gilbertella persicaria*. MARTHA J. POWELL, CHARLES E. BRACKER, and D. JAMES MORRÉ, Department of Botany and Plant Pathology, Purdue University, West Lafayette, Indiana 47907.—Mitochondria, vacuoles, plasma membranes, and vesicles with attached ribosomes from homogenized germlings of *Gilbertella persicaria* equilibrate at the 1.3/1.4 M interface in sucrose gradients. Differential centrifugation in sucrose and Ficoll gradients results in the additional separation of the mixed membranes into three fractions: one containing predominantly intact mitochondria, another composed of vacuoles and ribosome-coated vesicles, and a third enriched in plasma membranes. Differences in thickness and symmetry of membranes and in contents of vesicles are used to distinguish these different classes of membranes. The abundance of ribosome-coated vesicles in the vacuole enriched fraction is surprising because rapidly growing hyphae of *G. persicaria* are practically devoid of rough endoplasmic reticulum. Reconstruction from micrographs of mitochondrial fragmentation and vesiculation show that most of the ribosome-coated vesicles originate from disrupted mitochondria. Superficial resemblance of mitochondrial vesicles to rough endoplasmic reticulum could lead to the fallacious attribution of mitochondrial properties to endoplasmic reticulum. So far, binding of

ribosomes to isolated mitochondrial membranes has been observed only in fungi.

Pectinase in the Serum Fraction of *Asclepias syriaca* L. Latex. KATHRYN WILSON, CRAIG NESSLER, and PAUL MAHLBERG, Indiana University.—A pectinase with a pH optimum of 5.2 is present in the serum fraction of the latex of the common milkweed, *Asclepias syriaca* L. The intrusive growth and extensive elongation of the non-articulated branched laticifers of this plant suggest the necessity for such an enzyme system that can dissolve the middle lamellae of cells adjacent to the laticifer and that can loosen the cell wall material of the laticifer itself. Pectinase activity, which has been shown by others to be involved in cell wall softening in fruit ripening as well as in middle lamella dissolution during leaf abscission and during pollen tube growth, was postulated to have similar critical functions in the elongation and intrusive growth of all non-articulated branching laticifers. The enzyme was partially purified from the serum fraction of fresh latex by dialysis and ammonium sulphate fractionation. Enzyme activity was detected by a viscometry assay using either pectin or polygalacturonic acid as a substrate. Activity was confined mainly to the 40-50% ammonium sulphate fraction.

Laticifers in the Stamens of the Opium Poppy, *Papaver somniferum* L. CRAIG L. NESSLER and PAUL G. MAHLBERG, Indiana University.—Articulated anastomosing laticifers were identified at both the light and electron microscopic levels in the stamens of the opium poppy, *Papaver somniferum* L. In thick sections prepared for light microscopy the walls of stamen laticifers stain darker than those of adjacent cells and their cytoplasm has a granular appearance. The ultrastructure of these cells is comparable to laticifers located elsewhere in the plant. They possess numerous vesicles of different sizes in their darkly stained cytoplasm. Cell wall perforation in stamen laticifers results from the gradual thinning of adjacent walls as it does in the laticifers found in other tissues of the plant. Laticifers in the stamen are located in the vascular bundle associated with the phloem where they form a continuous system from the filament into the anther.

The Chromatographic Migration of Cannabinoids as Resolved by Thin-Layer and Gas Chromatography. PAUL G. MAHLBERG, JOHN K. HEMPHILL and JOCELYN C. TURNER, Indiana University.—Studies of the chromatographic migration of cannabinoids extracted from a Mexican strain of *Cannabis sativa* L. (marijuana) are described. Thin-layer chromatograph was employed to characterize the extraction procedure for routine analysis of known geographical strains of *Cannabis*. At least three 1-hour extraction periods were required for complete extraction of total cannabinoids. Concentration of these aliquots was adequately performed by either a vacuum oven (60) or nitrogen evaporation (ice bath) and were compared with results derived from flash evaporation. Variation of cannabinoid migration and order of resolution on reversed phase plates was observed to be influenced by the duration of air drying and/or the impregnation of chromatographs with various ratios of N' N' methyl formamide: carbon tetrachloride.

Gas chromatographic analysis of eluted cannabinoids derived from regions of the thin-layer chromatographs will be discussed.

Chemically Induced Cytoplasmic Inclusions in Canine Hepatic Cells. STEPHEN D. BARNARD and STANLEY D. WARNER, The Dow Chemical Company, Indianapolis, Indiana 46268.—Routine toxicologic screening of an experimental imidazoline compound revealed hyaline cytoplasmic inclusions in canine hepatic cells when examined at the light microscopy level. Additionally, histochemistry indicated these chemically-induced inclusions to be lipoprotein. Treatment withdrawal appeared to result in reversal to normal morphology.

For subsequent ultrastructural investigations, four adult Beagles, two per sex, were given daily intravenous imidazoline doses of 10 mg per kg of body weight. After dosing for ten consecutive days, the animals were removed from drug treatment; this post-dosing period varied in duration per individual. In addition to hepatic tissues obtained at necropsy, liver biopsies were performed at prescribed time periods during the experiment. Ultrastructural examinations of these tissues disclosed large ($6\text{--}12\mu$), predominantly finely-granular cytoplasmic inclusions in hepatic cells. These were found to be, at least in part, membrane limited. Explanation by sequestration appears to be contraindicated due to the absence of glycogen and paucity of organelles in these inclusions. Hepatic cell inclusions do, however, contain mitochondrial remnants, lysosomal elements and numerous myelin figures. Other hepatic cell response to imidazoline includes a proliferated smooth endoplasmic reticulum, dilated Golgi vesicles and apparent increases in numbers of microbodies.

Evidence for Fusion of Artificial and Natural Membranes. CHARLES W. GOFF and WAYNE E. MAGEE, Indiana State University and The University of Texas at San Antonio.—The fate of antigenic determinants incorporated into the lipid bilayer of liposomes was studied by the antibody-peroxidase conjugate immunocytochemical method after interaction of the liposomes with HeLa cells. The artificial membrane markers were transferred to the cell membrane even at $4\text{--}7^\circ\text{C}$ (well below the phase transition of all membrane lipids). Initial results indicate that label incorporated into relatively rigid liposomes (*i.e.* those containing cholesterol, sphingomyelin, and stearylamine) does not occur over as great a proportion of the HeLa cell surface as does that incorporated into lysolecithin-containing liposomes. Whether this is due to greater rates of fusion of the latter liposomes with cells or to greater rate of lateral diffusion of the liposomal marker after fusion is not yet known.

Effect of Drugs on Mouse Embryo Hearts in Organ Culture Visualized by Acoustic Microscopy. R. C. EGGLETON*, L. W. KESSLER**, F. S. VINSON* and G. B. BODER†; *Fortune-Fry Research Labs of the Indianapolis Center for Advanced Research and Indiana University School of Medicine, Indianapolis; **Sonoscan, Inc., Bensenville, Ill., and †Lilly Research Laboratories, Indianapolis.—A method has been developed for sustaining mouse embryo hearts in organ culture for extended

periods of time on the stage of an acoustic microscope. A culture chamber was fabricated to supply the hearts with a continuous flow of oxygenated culture medium to maintain contractile function. Simultaneous acoustic and optical viewing of the hearts permits more complete observation of the contractile events than heretofore possible. Anatomical features of the heart such as atria, ventricles, coronaries and valves have been observed. A group of hearts has been maintained simultaneously in the chamber for several days. The hearts may be in various physiological conditions, e.g. synchronous, asynchronous, rhythmic or arrhythmic. Drugs are introduced into the chamber either by pulsing (as short as 5 sec. exposure) or using a continuous perfusing. The effectiveness of these agents in restoring normal behavior can be evaluated. A videotape will be presented to describe the method and results.

Effect of Dietary Magnesium on Secretion of Serum Lipoproteins in Hyperlipoproteinemic Rabbits¹

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Abstract

Hyperlipoproteinemia was induced in rabbits by diets and ethanol. Golgi apparatus were disoriented and large accumulations of lipid appeared in smooth endoplasmic reticulum (SER) of the apical cytoplasm. When the diet was supplemented with magnesium, cholesterol levels were significantly lowered. The increased magnesium also appeared to maintain functional hepatic Golgi apparatus as well as result in a reduction in lipid deposits in the SER. An involvement of lysosomes in the latter was indicated.

Introduction

Two pathways are involved in the secretion of serum lipoproteins by the liver (8). 1) Protein synthesis is in the rough endoplasmic reticulum with modification and glycosylation in the Golgi apparatus. Secretory vesicles leave the distal face of the Golgi apparatus, carrying their contents to the cell surface where the lipoprotein is discharged into the capillary space. 2) The proteins are synthesized in rough endoplasmic reticulum with lipid addition in the smooth endoplasmic reticulum. Vesicles bud off the smooth endoplasmic reticulum and empty their contents at the cell surface into the blood stream. The proportion of lipoproteins following this route has not yet been determined. It is assumed that these lipoproteins are less glycosylated than those following the first pathway.

Hyperlipoproteinemia can be induced with high fat diet and ethanol (1,4,5,6,9). Magnesium was selected to ameliorate the effects of such a dietary regimen in rabbits since there is evidence of magnesium deficiency in human alcoholics (3) as well as experimental animals maintained on atherogenic diets (5,6,9). Early atherosclerotic lesions induced by atherogenic diet are diminished (or retarded) by increasing dietary magnesium (5,6,9).

The present study investigated the effects of atherogenic diet and alcohol on the liver cell, particularly the secretory mechanism. This study also shed light on the modifying role of increased dietary magnesium on these altered secretory patterns.

Materials and Methods

New Zealand male white rabbits were maintained in separate cages on three different diets. Group A, received standard rabbit pellets and water, *ad libitum*; Group B, atherogenic diet (#170060, Teklad) and 40% ethanol, *ad libitum*; Group C, atherogenic diet enriched with magnesium

¹ Work supported in part by a grant from the Indiana Heart Association.

as magnesium oxide to ten times standard dietary levels and 40% ethanol, *ad libitum*.

Blood was collected from the ear vein each week. Total serum cholesterol was determined by the direct serum method (7).

Animals were sacrificed after nine weeks. Gross observations were made and liver samples from each were prepared for electron microscopy. Fixation was overnight in cold 1% osmium tetroxide buffered with 0.1 M sodium phosphate at pH 7.0. Samples were acetone dehydrated and embedded in Luft's epon. Sections were post stained with lead citrate.

Results and Discussion

Hyperlipoproteinemia was discernible after one week of an atherogenic diet and ethanol (Fig. 1), reaching a high and plateauing in five weeks. Although all the rabbits on these diets exhibit increased levels of serum cholesterol, the serum of those receiving the magnesium enriched atherogenic diet had 200 mg % less cholesterol than those without magnesium.

Growth of rabbits on the atherogenic diet and ethanol was retarded. The coats of these rabbits was ruffled and unkempt, but much less so in the rabbits receiving the magnesium enriched diet. The liver was caseous in texture, had a brownish color and fractured easily. These symptoms could have been the result of the diet, alcohol intoxication, or, in the one group, magnesium deficiency.

Thin sections of control liver (Fig. 2) had ultrastructural characteristics typical of mammalian liver with lipoprotein bearing secretory vesicles originating at the Golgi apparatus.

In the liver of rabbits receiving atherogenic diet (Fig. 3), Golgi apparatus were sparse; those still recognizable were diminutive and disorganized. Secretory vesicles when present were void of lipoprotein particles. Near the apical portions of cells large accumulations of lipid were found in association with smooth endoplasmic reticulum. The rough endoplasmic reticulum of the cell was swollen, the lumina contained granular material of moderate electron density.

When the atherogenic diet was enriched with magnesium, the Golgi apparatus in liver thin sections (Fig. 4) conformed more closely to the typical image. Some lipoprotein particles were visible in secretory vesicles. Near the apical portion of the cell were numerous autophagic vacuoles and lysosomes containing large residual bodies. The lipid deposits in the smooth endoplasmic reticulum are greatly reduced. The rough endoplasmic reticulum remained distorted and swollen.

These observations suggest that an atherogenic diet accompanied by ethanol disrupts the secretory mechanisms in the liver. Large amounts of dietary magnesium appear to restore or maintain some normalcy to the secretory mechanism. The large number of autophagic vacuoles and lysosomes in the livers of animals receiving the magnesium-supplemented diet implicate the lysosomal apparatus in the restoration or maintenance process.

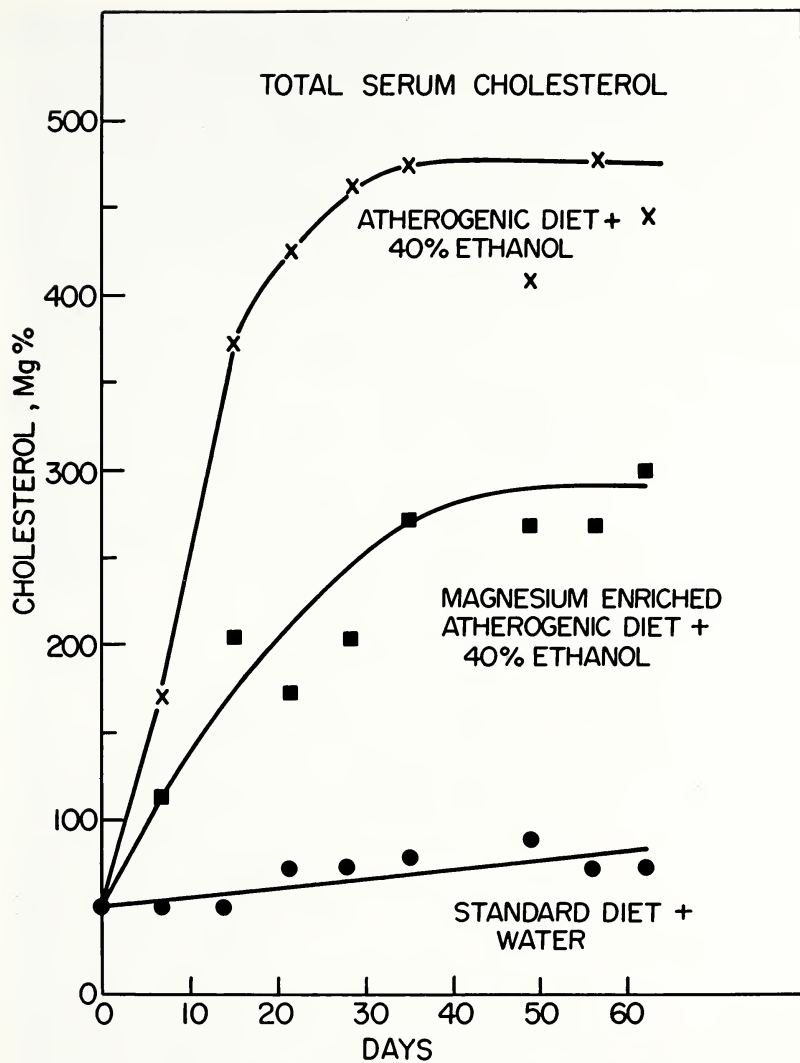


FIGURE 1. Total serum cholesterol determined weekly using the direct serum method.

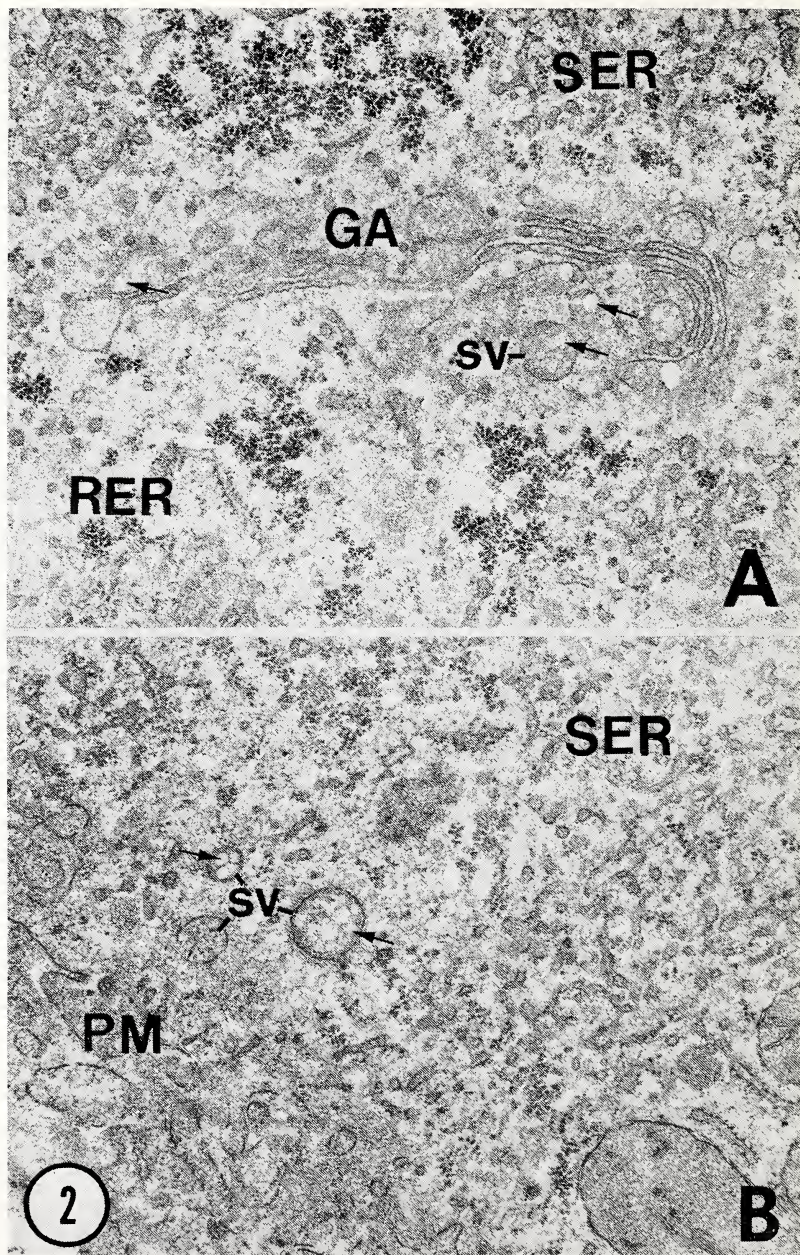


FIGURE 2. Thin sections of liver from control rabbit.

A. Golgi apparatus (GA) with secretory vesicle (sv) containing very low density lipoproteins (arrows). SER = smooth endoplasmic reticulum. RER = rough endoplasmic reticulum. X 23,800.

B. Secretory vesicle (sv) containing very low density lipoproteins (arrow) near the apical portion of the cell. PM = plasma membrane. SER = smooth endoplasmic reticulum. X 23,800.

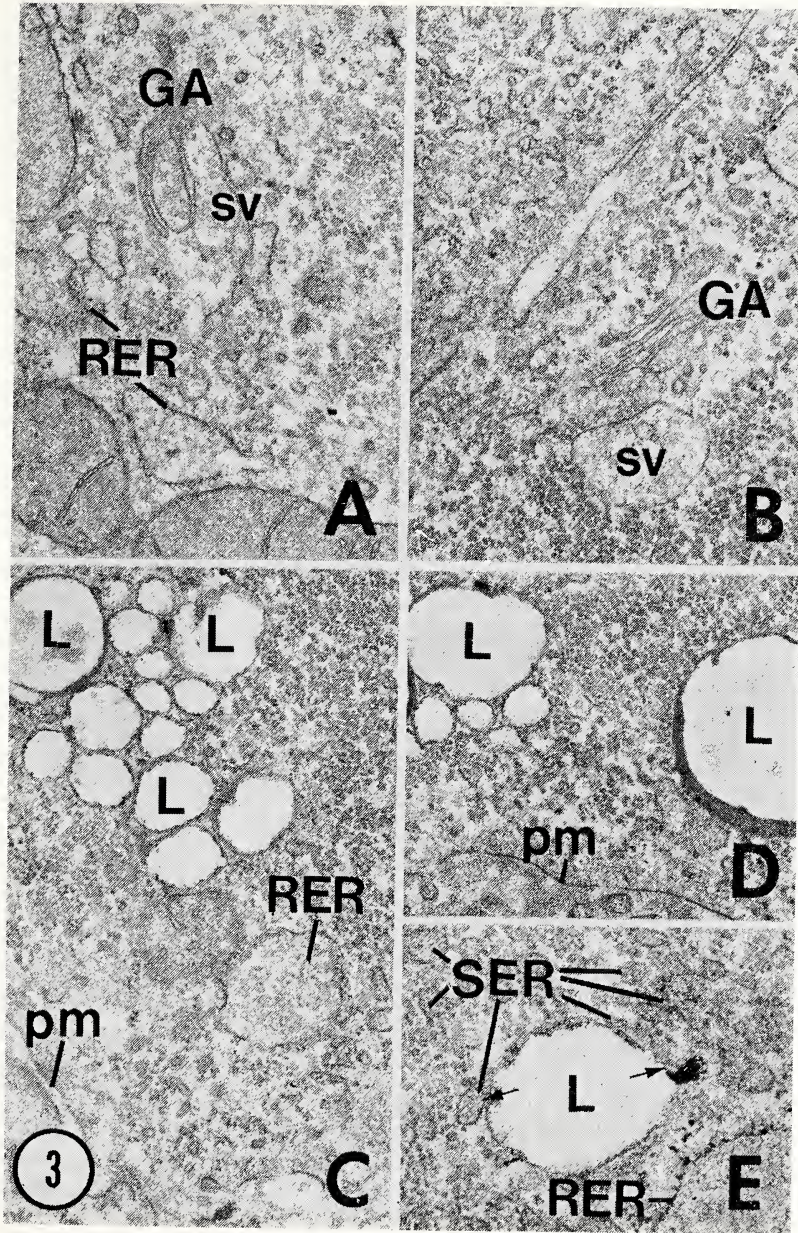


FIGURE 3. Thin sections of liver from rabbit on atherogenic diet and 40% ethanol. A and B. Golgi apparatus (GA) irregular in appearance and secretory vesicles (sv) containing very low density lipoprotein particles were sparse. Note swollen rough endoplasmic reticulum (RER). X 23,800. C and D. Large lipid containing vesicles (L) in apical portion of cell. pm = plasma membrane. RER = rough endoplasmic reticulum. X 23,800. E: Lipid containing vesicle (L) showing membrane continuities (arrows) with smooth endoplasmic reticulum (SER). pm = plasma membrane. RER = rough endoplasmic reticulum. X 35,000.

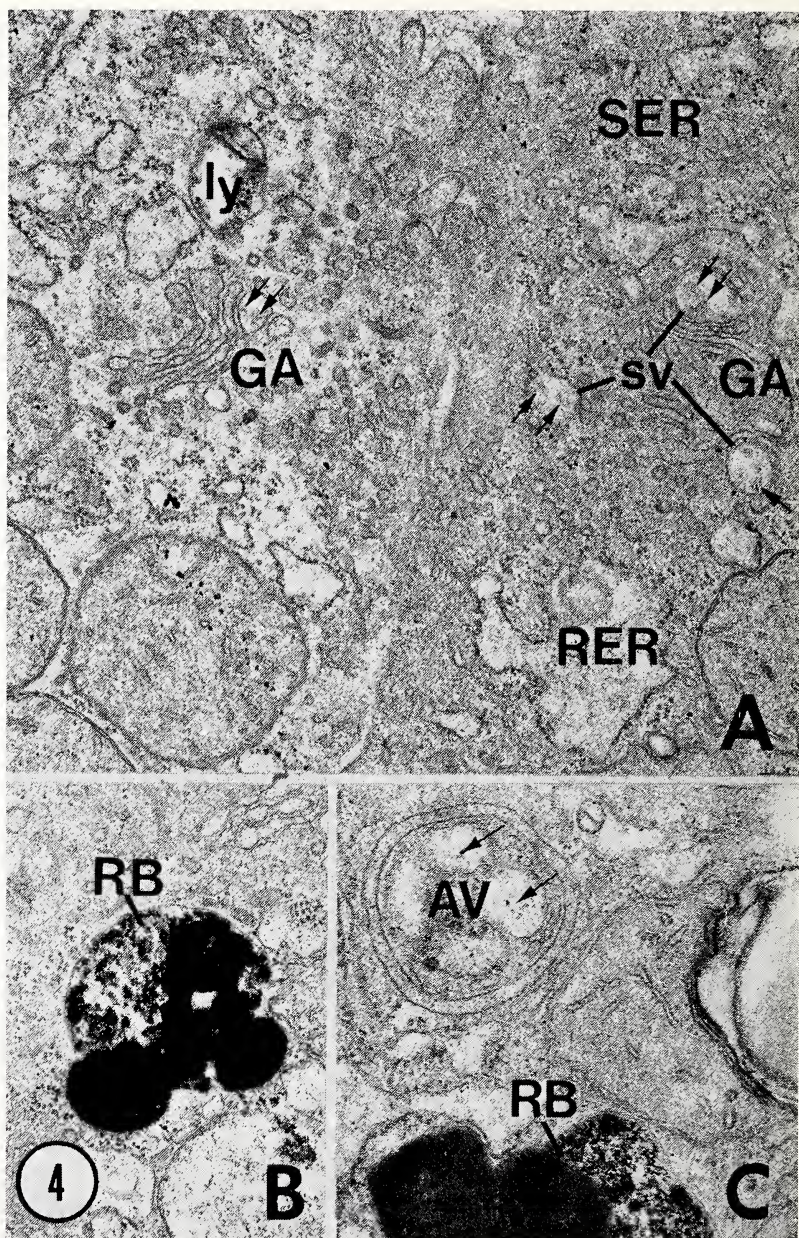


FIGURE 4. Thin sections of liver from rabbit on MgO enriched atherogenic diet and 40% ethanol.

A. Golgi apparatus (GA) more nearly normal in appearance with secretory vesicles (sv) showing some very low density lipoprotein (arrow) particles. Note the swollen rough endoplasmic reticulum (RER), ly = lysosome. X 32,800.

B. Lysosome containing residual bodies (RB) X 23,800.

C. Autophagic vacuoles (AV) containing lipoprotein material (arrow). Large residual body (RB) in lysosome. X 40,800.

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Control of Photosynthesis by CO₂: Evidence for A Bicarbonate-Inhibited Redox Feedback in Photosystem II¹

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Abstract

The role of bicarbonate or CO₂ as a regulator of electron flow was studied in spinach chloroplasts. It was found that bicarbonate inhibited a proposed cyclic pathway around Photosystem II while stimulating the forward flow of electrons toward Photosystem I. Such behavior would result in increased rates of ATP and NADPH formation by the green plant. It was also found that in isolated chloroplasts other compounds, such as chelators, uncouplers, or any inhibitor of silicomolybdic acid reduction in a DCMU-insensitive pathway around PS II would increase the forward flow of electrons to Photosystem I, provided that the compound itself was not inhibitory of ferricyanide or dimethylbenzoquinone reduction in Photosystem II, or inhibited the H₂O → methyl viologen pathway which covers both photosystems. Bathocuproine in low concentrations (10-15 μg/ml) turned out to be a model compound in all respects.

Introduction

Stimulation of photosynthetic reactions by CO₂ was discovered by Boyle (7) but investigated in greater detail by Warburg and Krippahl (13), Good (9), and many others. Until recently, conflicting reports were obtained. In 1973, Stemler and Govindjee (11) discovered that the bicarbonate ion, not CO₂, was a critical factor in photosynthetic O₂ evolution. They used bicarbonate-depleted chloroplasts to show up to five-fold increases in Hill reaction rates with added bicarbonate. Bicarbonate also increases the amount of delayed light emission from chloroplasts and has an effect on chlorophyll a fluorescence transients (12). In conclusion, bicarbonate affects oxygen evolution on the oxidizing side of Photosystem II and also has an effect on the reducing side of PS II in isolated chloroplasts (14).

Based on Govindjee and associates' discoveries about the effect of CO₂, we in this paper would like to propose an alternative hypothesis to explain the known facts. The role of CO₂ or bicarbonate in photosynthesis may be that of a regulator: shutting off a cyclic flow of electrons around PS II and stimulation of the Hill reaction in a forward flow of electrons toward PS I resulting in increased NADPH production.

Materials and Methods

Market spinach was used for making chloroplasts, using Jagendorf and Avron's method (10). The grinding and suspension medium was 0.4 M sucrose with 0.05 M NaCl. Chlorophyll was determined according to Arnon (1).

All PS I and II assays were done polarographically measuring either O₂ uptake or evolution with a Clark-type electrode attached to

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a Yellow Springs Instrument Oxygen Monitor and recorded with a Honeywell recorder.

The reaction mixture for measuring oxygen evolution associated with ferricyanide reduction by PS II in presence of DBMIB contained in 1.5 ml total volume: chloroplasts (50 μ g), Trizma-Mes, 37.5 μ moles, 3 μ moles NH_4Cl , 3 μ moles MgCl_2 , 2.5 μ moles $\text{K}_3\text{Fe}(\text{CN})_6$, pH 7.0, and 0.06 μ g DBMIB. The $\text{H}_2\text{O} \rightarrow \text{DMBQ}$ reaction medium in presence of DBMIB contained all of the above ingredients except 2.5 μ moles DMBQ in place of ferricyanide. The $\text{H}_2\text{O} \rightarrow \text{MV}$ reaction medium contained the same ingredients except 5 μ moles MV in place of ferricyanide. No DBMIB was present in this case. The $\text{H}_2\text{O} \rightarrow \text{SM}$ reaction contained the same amount of buffer with NH_4Cl and MgCl_2 but 0.2 mg SM in place of ferricyanide and 0.3 μ moles DCMU substituted for DBMIB. The dark preincubation period for each assay was 2 min. The reaction rates are expressed as μ equivalents/mg chlorophyll/hr.

Bicarbonate for adding to assays was made fresh daily. All other additives—chelators, uncouplers, quinone analogs—were dissolved in ethanol (sometimes heated on waterbath) and added to reaction mixtures not to exceed 25 μ l/1.5 ml. In Fig. 1-11 the concentration of additives is expressed as μ moles or μ g/1.5 ml.

Results and Discussion

The aim of this study was to show that an alternative interpretation of the CO_2 or bicarbonate effect on photosynthesis as proposed by Govindjee and associates (11, 12, 14) is also possible. Assuming a cyclic flow of electrons around PS II, as is known to occur in PS I (2) all that is needed for the stimulation of forward electron flow in the electron transport chain of chloroplasts is a regulator to inhibit the PS II cycle. We can show that bicarbonate among other substances (Table 1, Fig. 1 and 2) inhibits silicomolybdic acid reduction in a DCMU-insensitive manner in the region of Q, the primary acceptor, in PS II (6, 8). This results in increased rates of other PS II reactions, such as ferricyanide or dimethyl-benzoquinone reduction. The $\text{H}_2\text{O} \rightarrow$

TABLE 1. *Factors Affecting Silicomolybdic Acid Reduction by Chloroplast Photosystem II.*

Additions	Stimulation or Inhibition of O_2 Evolution (% of Control)	
	$\text{H}_2\text{O} \rightarrow \text{SM}$	$\text{H}_2\text{O} \rightarrow \text{ferricyanide}$
DCMU (4.5 μ moles) -----	-8	-100
Ethanol (50 μ l) -----	-52	-19
Bathophenanthroline (25 μ g) -----	-20	+24
Orthophenanthroline (5 μ g) -----	+29	-100
Sodium bicarbonate (100 μ g) -----	-50	-12
Potassium permanganate (25 μ moles) -----	-75	-20
Tertoctyleatechol (80 μ moles) -----	-63	+234

Reaction conditions as in Methods.

The control rates for the $\text{H}_2\text{O} \rightarrow \text{SM}$ (+ DCMU) reaction varied from 252-312 μ equiv./mg chlorophyll/hr, for the $\text{H}_2\text{O} \rightarrow \text{FeCy}$ (+ DBMIB) reaction from 250-360. + indicates stimulation.

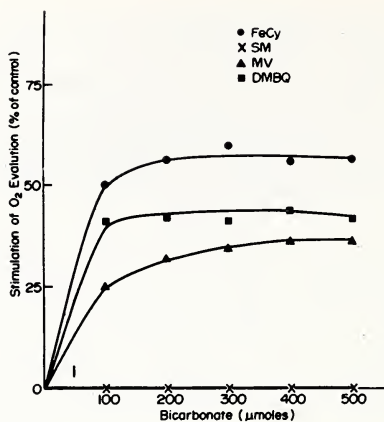


FIGURE 1. The effect of bicarbonate on 4 chloroplast reactions: $H_2O \rightarrow$ ferricyanide ($\bullet$), $H_2O \rightarrow$ silicomolybdic acid (X), $H_2O \rightarrow$ methyl viologen (Δ), and $H_2O \rightarrow$ dimethylbenzoquinone ($\blacksquare$) in bicarbonate-depleted chloroplasts. Reaction conditions stated in Materials and Methods. The control rate for $H_2O \rightarrow FeCy$ was 203 μ equiv./mg chlorophyll/hr, for $H_2O \rightarrow SM-O_2$, for $H_2O \rightarrow MV-519$, and for $H_2O \rightarrow DMBQ-361$.

methyl viologen reaction which encompasses both photosystems is also stimulated (Fig. 1, 2). By definition this makes CO_2 or bicarbonate the regulator mechanism of electron flow in chloroplasts. Subsequently, the forward flow of electrons results in more efficient energy conservation by the chloroplasts and the whole green plant.

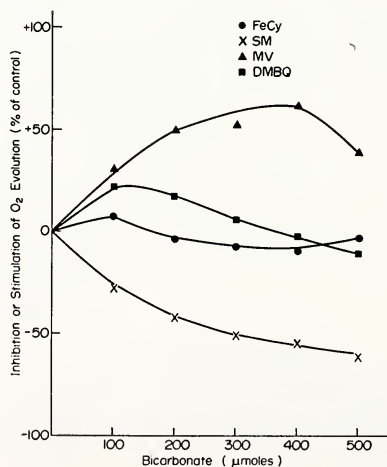


FIGURE 2. The effect of bicarbonate on 4 chloroplast reactions: $H_2O \rightarrow$ ferricyanide ($\bullet$), $H_2O \rightarrow$ silicomolybdic acid (X), $H_2O \rightarrow$ methyl viologen (Δ), and $H_2O \rightarrow$ dimethylbenzoquinone ($\blacksquare$) in sucrose-sodium chloride chloroplasts in presence of NH_4Cl . Reaction conditions as in Fig. 1. The control rate for $H_2O \rightarrow FeCy$ was 305 μ equiv./mg chlorophyll/hr, for $H_2O \rightarrow SM-214$, for $H_2O \rightarrow MV-158$, for $H_2O \rightarrow DMBQ-$

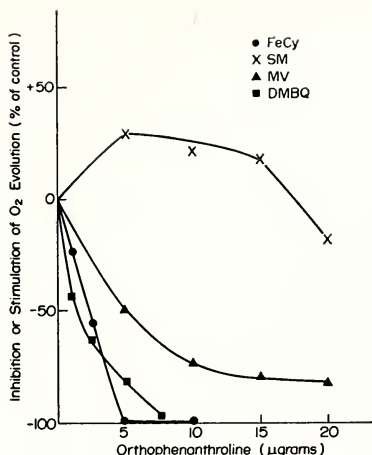


FIGURE 3. The effect of orthophenanthroline on 4 chloroplast reactions: $H_2O \rightarrow$ ferricyanide (●), $H_2O \rightarrow$ silicomolybdic acid (X), $H_2O \rightarrow$ methyl viologen (Δ), and $H_2O \rightarrow$ dimethylbenzoquinone (■) in sucrose-sodium chloride chloroplasts. Reaction conditions as in Fig. 1.

Another way of testing the proposed model of bicarbonate acting as a regulator of electron flow in chloroplasts is to inhibit the forward flow of electrons toward PS I and observe what effect this has on the cyclic system around PS II. The assumption is that under these conditions increased rates of silicomolybdic acid reduction might be

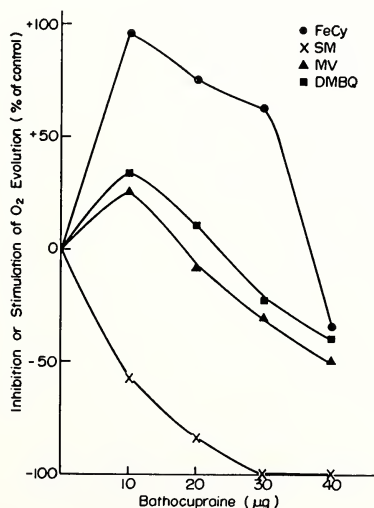


FIGURE 4. The effect of bathocupraine on 4 chloroplast reactions: $H_2O \rightarrow$ ferricyanide (●), $H_2O \rightarrow$ silicomolybdic acid (X), $H_2O \rightarrow$ methyl viologen (Δ), and $H_2O \rightarrow$ dimethylbenzoquinone (■) in sucrose-sodium chloride chloroplasts. Reaction conditions as in Fig. 1.

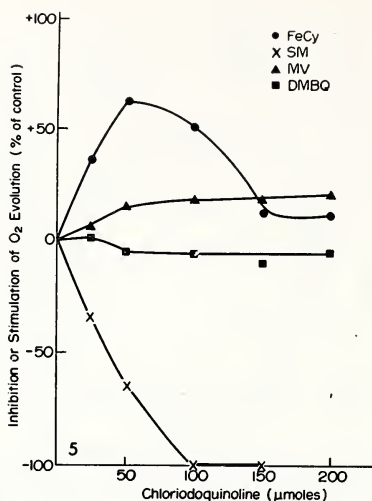


FIGURE 5. The effect of chloridoquinoline on 4 chloroplast reactions: $H_2O \rightarrow$ ferricyanide (●), $H_2O \rightarrow$ silicomolybdic acid (X) $H_2O \rightarrow$ methyl viologen (Δ), and $H_2O \rightarrow$ dimethylbenzoquinone (■) in sucrose-sodium chloride chloroplasts. Reaction conditions as in Fig. 1.

observed. This is indeed the case, as seen in Fig. 3 using orthophenanthroline, a chelator, to inhibit ferricyanide and dimethylbenzoquinone reduction in PS II and the $H_2O \rightarrow$ methyl viologen reaction which covers both photosystems. Orthophenanthroline is known to inhibit electron

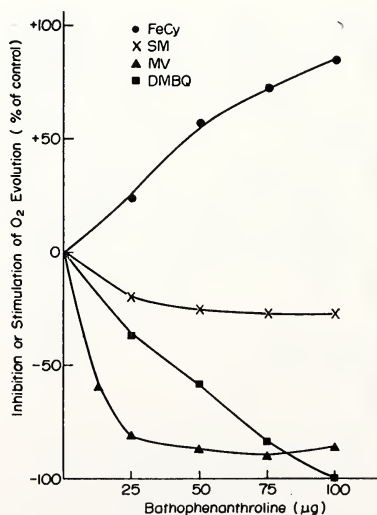


FIGURE 6. The effect of bathophenanthroline on 4 chloroplast reactions: $H_2O \rightarrow$ ferricyanide (●), $H_2O \rightarrow$ silicomolybdic acid (X), $H_2O \rightarrow$ methyl viologen (Δ), and $H_2O \rightarrow$ dimethylbenzoquinone (■) in sucrose-sodium chloride chloroplasts. Reaction conditions as in Fig. 1.

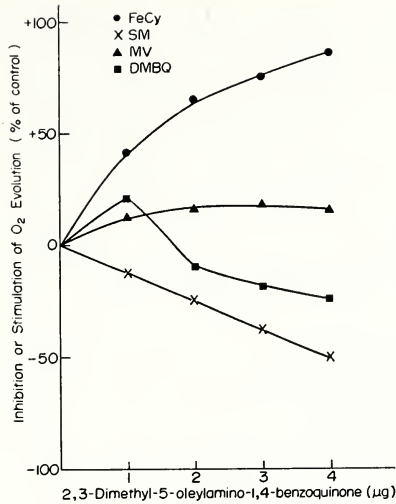


FIGURE 7. The effect of 2,3-dimethyl-5-oleylamino-1,4-benzoquinone on 4 chloroplast reactions: $H_2O \rightarrow$ ferricyanide ($\bullet$), $H_2O \rightarrow$ silicomolybdic acid (X), $H_2O \rightarrow$ methyl viologen (Δ), and $H_2O \rightarrow$ dimethylbenzoquinone ($\blacksquare$) in sucrose-sodium chloride chloroplasts. Reaction conditions as in Fig. 1.

flow close to DCMU, although not at the same site (3), but it stimulates silicomolybdic acid reduction in low concentrations (Fig. 3). A similar effect, namely, lowered rates of forward electron transport toward PS I have been shown in absence of bicarbonate in bicarbonate-depleted chloroplasts by Stemler and Govindjee (11). The reverse

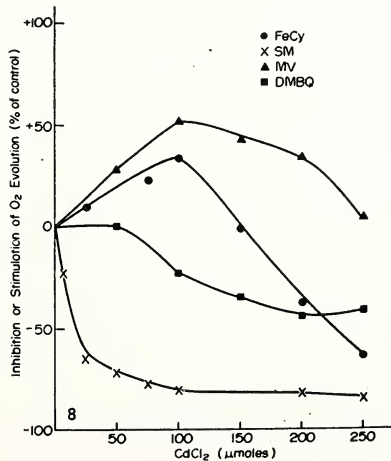


FIGURE 8. The effect of $CdCl_2$ on 4 chloroplast reactions: $H_2O \rightarrow$ ferricyanide ($\bullet$), $H_2O \rightarrow$ silicomolybdic acid (X), $H_2O \rightarrow$ methyl viologen (Δ), and $H_2O \rightarrow$ dimethylbenzoquinone ($\blacksquare$) in sucrose-sodium chloride chloroplasts. Reaction conditions as in Fig. 1.

effect, i.e. stimulation of silicomolybdic acid reduction in bicarbonate-depleted chloroplasts is difficult to show because the depletion process inactivates silicomolybdic acid reduction (Fig. 1). This inactivation may not be due to the low pH used (pH 5-6) but to the high salt (0.25 M NaCl) concentration recommended by Stemler and Govindjee (11) for the depletion of CO_2 in chloroplasts. However, the inability to show stimulation of silicomolybdic acid reduction in isolated bicarbonate-depleted chloroplasts by CO_2 or bicarbonate does not invalidate the proposed hypothesis that agents which inhibit cyclic electron flow around PS II stimulate the forward flow of electrons which leads to increased PS I rates and, subsequently, increased ATP production by plants.

Best experimental proof for the hypothesis of CO_2 or bicarbonate as regulators of electron flow in photosynthesis comes from using other types of compounds, especially chelators and uncouplers. In this study 3 known chelators—bathocuproine, bathophenanthroline and chloriodoquinoline—were used. Bathocuproine (Fig. 4) which strongly inhibits silicomolybdic acid reduction in presence of DCMU (5) stimulates ferricyanide and dimethylbenzoquinone reduction by PS II and the flow of electrons from $\text{H}_2\text{O} \rightarrow$ methyl viologen. Chloriodoquinoline gave similar results (Fig. 5). Bathophenanthroline, another lipophilic chelator like bathocuproine, stimulates only ferricyanide reduction but inhibits all the other reactions studied. Bathophenanthroline-sensitive sites were found in the region between DCMU and plastoquinone by Barr and Crane (4). 2-3-Dimethyl-5-oleylamino-1,4-benzoquinone, a plastoquinone analog, acted in a similar manner (Fig. 7). Structurally, this quinone may also act as a chelator, so that it is not surprising to see an effect as with bathophenanthroline. Bathophenanthroline is pre-

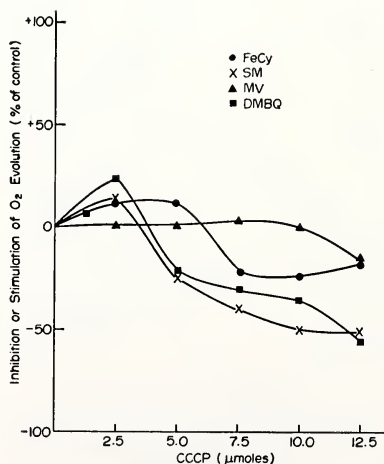


FIGURE 9. The effect of CCCP on 4 chloroplast reactions: $\text{H}_2\text{O} \rightarrow$ ferricyanide (●), $\text{H}_2\text{O} \rightarrow$ silicomolybdic acid (X), $\text{H}_2\text{O} \rightarrow$ methyl viologen (Δ), and $\text{H}_2\text{O} \rightarrow$ dimethylbenzoquinone in sucrose-sodium chloride chloroplasts in presence of NH_4Cl . Reaction conditions as in Fig. 1.

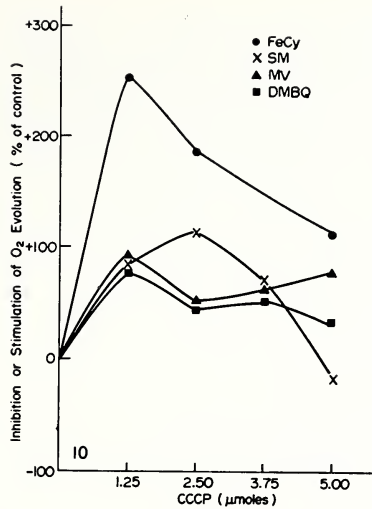


FIGURE 10. The effect of CCCP on 4 chloroplast reactions: $H_2O \rightarrow$ ferricyanide (●), $H_2O \rightarrow$ silicomolybdic acid (X), $H_2O \rightarrow$ methyl viologen (Δ), and $H_2O \rightarrow$ dimethylbenzoquinone in sucrose-sodium chloride chloroplasts in absence of NH_4Cl . Reaction conditions as in Fig. 1 except no NH_4Cl present.

sumably acting on a metalloprotein complex, such as a non-heme iron, close to the phosphorylation site of PS II.

Acting in a different manner but giving the postulated results is cadmium chloride (Fig. 8). Its mode of action is unknown but the fact that it inhibits dimethylbenzoquinone reduction by PS II in higher

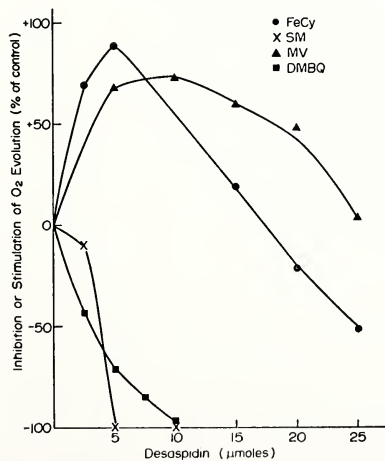


FIGURE 11. The effect of desaspadin on 4 chloroplast reactions: $H_2O \rightarrow$ ferricyanide (●), $H_2O \rightarrow$ silicomolybdic acid (X), $H_2O \rightarrow$ methyl viologen (Δ), and $H_2O \rightarrow$ dimethylbenzoquinone (■) in sucrose-sodium chloride chloroplasts. Reaction conditions as in Fig. 1.

concentrations suggests its closeness to the phosphorylation site in PS II.

An uncoupler like CCCP in presence of NH_4Cl shows only a slight stimulation of all 4 partial electron transport reactions studied (Fig. 9) but in absence of NH_4Cl greater stimulation is seen (Fig. 10). Silicomolybdic acid reduction is inhibited at a lower concentration (5 μmoles) while the other reactions still show varying degrees of stimulation due to uncoupling of electron transport from photophosphorylation. Desaspidin, another uncoupler, inhibits silicomolybdic acid reduction while stimulation of ferricyanide and the $\text{H}_2\text{O} \rightarrow$ methyl viologen reaction occurs (Fig. 11). Dimethylbenzoquinone reduction is not stimulated according to predictions because there may be an inhibition site in its pathway.

Acknowledgements:

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Study of the Translocation of the Methyl Group in *Triticum aestivum* (Gramineae)

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Abstract

The incorporation and the translocation of the methyl group in winter wheat was investigated during the early germination period. Absorption of S-methyl-L-methionine- $^{14}\text{CH}_3$, or its methyl group, by wheat roots was ascertained and uptake of the tagged methyl group was observed in the seed parts for 1, 2, and 3 days' germination and in the root and shoot by the third day of germination using liquid scintillation studies. Autoradiographic analysis of labeled tissue suggests translocation of the methyl group to meristematic regions and to the walls of the elongating cells in the region of cell elongation in root tissue.

Introduction

Transmethylation, the transfer of a methyl group *in toto*, is by far the major pathway for the formation of biologically important methylated compounds. Methionine, the key compound in this transmission of the methyl group, may be formed by the methylation of homocysteine from either S-adenosyl-L-methionine or S-methyl-L-methionine. This homocysteine methyltransferase (EC 2.1.1.10) has been demonstrated in *Aerobacter aerogenes* (9), *Escherichia coli* K-12 (10), *Saccharomyces cerevisiae* (11), jack bean meal (1), and in extracts of the seeds of a number of higher plants, including pea, lima bean, and corn (14). In these seed extracts it was demonstrated that S-methyl-L-methionine is a more efficient methyl donor than S-adenosyl-L-methionine. In addition, these studies are significant because they are the first demonstration of S-methyl-L-methionine:homocysteine methyltransferase activity in a system which possesses the substrate in detectable amounts.

A second direct transmethylation reaction, methionine S-methyltransferase (EC 2.1.1.12), has been studied in jack bean roots (4), pea, pumpkin, kohlrabi and sesbania seedlings (12). A recent comparative study of homocysteine methyl transferase and methionine S-methyl transferase systems in winter wheat has shown these two enzyme systems to be active in the dry seed, soaked seed, and the parts of the germinating wheat seedling and to display peaks at various days over the fourteen day germination study (2).

All of the studies cited above suggest general distribution of S-methyl-L-methionine in higher plants and thus far the key role described for S-methyl-L-methionine is that of a methyl donor in its conversion to methionine. It is the contention of several researchers that S-methyl-L-methionine serves as a methyl donor for compounds other than homocysteine. Sato, Bonner and workers analyzed the fate of sulfur and methyl-labeled S-methyl-L-methionine supplied *in vivo* to oat seedling sections (8). These workers found that the total recovery of the methyl group of methyl-labeled S-methionine in several products was less than the recovery of the sulfur-labeled compound and suggested

that the methyl groups of S-methyl-L-methionine were used in some reaction in which the sulfur does not participate. The recent comparison of homocysteine methyltransferase and methionine S-methyltransferase systems in winter wheat has suggested that peak activities were related to the seedlings' requirements for methyl groups in the formation of various compounds (2). S-methyl-L-methionine could be transferring methyl groups to nucleic acid bases, histones, or pectic substances. There is much literature to support the methylation of these structures. The following study was undertaken to study the role of the methyl group donated by S-methyl-L-methionine in winter wheat.

Materials and Methods

All common laboratory chemicals used were reagent grade commercial products. Labeled compound, L-methionine-(methyl- ^{14}C) sulfonium iodide, was purchased from International Chemical and Nuclear Corporation, Irvine, California.

The experimental plant used in this study, *Triticum aestivum*, ssp. *vulgare* (Vill., Host) MacKey variety Gaines/CI 13448 was stored in the seed state under vacuum at 4 C. After disinfection and soaking, seedlings were grown in a growth chamber for varying germination periods.

Uptake of S-methyl-L-methionine- $^{14}\text{CH}_3$ by roots:

To establish absorption of S-methyl-L-methionine- $^{14}\text{CH}_3$ by wheat roots an experiment such as that done by Sato (7) was performed. Entire plants and excised roots were incubated in a solution of S-methyl-L-methionine- $^{14}\text{CH}_3$ (specific activity of this solution was $4 \times 10^{-2} \mu\text{Ci}/\mu\text{M}/\text{ml}$). In order to monitor uptake by the plant tissue, aliquots of this solution were removed daily. This solution was placed in a Triton X-100 scintillation fluid and counted in a Beckman model LS-150 liquid scintillation spectrometer.

Detection of S-methyl-L-methionine- $^{14}\text{CH}_3$ in solubilized tissue:

Actual uptake of S-methyl-L-methionine- $^{14}\text{CH}_3$ was measured in solubilized tissue. Plants incubated in this labeled substance were rinsed well with distilled water, separated into seedling parts, layered with NCS tissue solubilizer and allowed to stand until solubilization was complete. Radioactivity was determined after adding Triton-containing scintillation fluid. To establish a difference between radioactive material absorbed and radioactive material remaining on the external parts of the seedling, both incubated unsolubilized and unincubated unsolubilized tissues were examined.

Detection of S-methyl-L-methionine- $^{14}\text{CH}_3$ by autoradiograms:

Plants were incubated in S-methyl-L-methionine- $^{14}\text{CH}_3$ in concentrations ranging from $0.1 \mu\text{Ci}/\mu\text{M}$ to $18.0 \mu\text{Ci}/\mu\text{M}$ for 5-120 minutes. After rinsing in distilled water, seedlings were fixed, dehydrated, infiltrated with paraffin, cut on the microtome at a thickness of 10 microns and placed on slides coated with gelatin-chrome alum (6). After deparaffination, the slides were ready for autoradiographic treatment and

analysis. All photographic procedures were carried out in a darkroom under a safelight containing a Wratten series 2 filter. Prepared slides were dipped in Kodak NTB₃ liquid emulsion and stored in a light proof box until development. Following development and fixation, slides were stained in gallocyanin-chromalum (3, 13), rinsed, dehydrated and mounted.

In all previous described studies, tests were performed in duplicate and repeated tests were conducted in order to establish reproducibility.

Results and Discussion

Table 1 shows a study of absorption of S-methyl-L-methionine-¹⁴CH₃ or its methyl group by wheat roots. At 24 hours the activity of the incubation solution for intact seedlings, previously germinated 1 or 2 days decreased about 33%. Decreases for periods longer than 24 hours were less, but were recorded at 62-67% at 96 hours. No loss of labeled material was noted in solutions lacking plant tissues. These data were interpreted to mean that S-methyl-L-methionine-¹⁴CH₃ or its methyl group, was being absorbed by the wheat roots.

TABLE 1. *Radioactivity of solution after incubation for intact seedlings and root fragments.*

Incubation Solutions ^a	Radioactivity (cpm) remaining after:			
	24 hr	48 hr	72 hr	96 hr
Control -----	2353	2410	2402	2500
Day 1 ^b				
Intact seedling -----	1611	1227	1052	945
Day 1 ^b				
Root fragments -----	2221	2199	2223	2204
Day 2 ^c				
Intact seedling -----	1684	1332	996	839
Day 2 ^c				
Root fragments -----	2122	2070	1868	1747

^a S-methyl-L-methionine-¹⁴CH₃ (specific activity of 4×10^{-2} μ Ci/ μ M/ml).

^b 24-hour germination before incubation.

^c 48-hour germination before incubation.

The rapid loss in label of the incubation solution after 24 hours and declining change throughout the remaining incubation period suggest a metabolic function related to absorption of S-methyl-L-methionine. It was considered that a contrast of the incorporation of the methyl group with proteolytic activity during the period shown in Table 1 would provide some information about mobility of the methyl group in winter wheat. In 1971, Allamong (2) studied protease activity in germinating wheat seedlings over a 14-day germination period. This study showed a peak activity through day 4 in the root tissue. The comparison of Allamong's study of protease activity in germinating wheat seedlings with those of comparable growth in this study of the uptake of the methyl group indicates that mobility and uptake may be related over the 4-day span investigated. In addition, Allamong's work indicated a

high level of S-methyl-L-methionine: homocysteine methyltransferase activity in the root for day 1, 2, and 3, followed by a drop to zero on the fourth day. These observations again suggest correlation of mobility and utilization of the S-methyl-L-methionine.

Results of the tissue solubilization of root, shoot, and seed parts of seedlings, 1 to 3 days' germination, after incubation in S-methyl-L-methionine- $^{14}\text{CH}_3$ are shown in Table 2. These data include a subtraction for background and a subtraction for residual radioactivity on the exterior of the seedling. These data indicate incorporation in the seed parts for day 1, 2, and 3; however, after subtraction, incorporation was indicated in the root and shoot only for day 3. Based on the previous study of protease activity in these tissues during early germination, S-methyl-L-methionine might not be expected until day 3 (2). This study supports this conclusion. Measured activity was quite high in the seed during day 1 and declines by day 2—at a time when protease activity indicates mobilization. By day 3, incorporation of the labeled S-methyl-methionine was indicated in both root and shoot tissue. This pattern was repeated in duplicate studies and found to be a reproducible result.

TABLE 2. *Radioactivity of incubated tissue.*^a

Tissue	Radioactivity incorporated after germination day:		
	1	2	3
Root -----	-----b	-----b	4608
Shoot -----	-----b	-----b	143
Seed -----	11699	465	4877

^a Data represents individual seedling solubilized with NCS tissue solubilizer.

^b ----- indicates net count (experimental-control) was equal to or less than zero. Control includes a factor for background and unsolubilized incubated tissue.

Autoradiograms were analyzed for the incorporation of the radioactive label and results are shown on Table 3. For each preparation, control slides of unincubated tissue, processed in exactly the same manner as the experimental tissue were included. The labeling of root meristematic tissue from days 1 through 4 was diffuse; label was observed throughout the tissue over both the cytoplasm and the nucleus and was not associated with any cell structure (Fig. 1). At times labeling was observed in the stele of the root as seen in cross sections. With a longer incubation time and an increase in unlabeled S-methyl-L-methionine, day 1 and 2 root tissue showed an interesting pattern, which is susceptible of a greater range of interpretation. Silver grains were observed within the walls of cells in the region of cell elongation (Fig. 2). These grains were continuous from slide to slide. No such pattern was observed in control slides. Labeling of the aleurone layer was observed in day 1 and 2, an observation corresponding to the levels of S-methyl-L-methionine: homocysteine methyltransferase activity as described by Allamong (2). Labeling was not observed in shoot tissue during this study. No labeling of the nuclear components among the

cells of shoot, root and seed were observed. The contention that methyl groups are necessary for differential methylation of nucleic acids or histones in winter wheat during germination and during daily development was not evidenced over this short germination period.

TABLE 3. *Incorporation of label into specific tissues of plant parts.*

Seedling part	Germination day	Incubation, minutes	Specific activity ^a	Tissue of incorporation ^b
root	1	30	18 μ Ci/ μ M/ml	meristematic
root	1	60	0.1 μ Ci/ μ M/ml	region of elongation, cell wall
seed	1	60	0.1 μ Ci/ μ M/ml	aleurone layer
root	2	30	18 μ Ci/ μ M/ml	meristematic
root	2	30	18 μ Ci/ μ M/ml	stele
root	2	60	0.1 μ Ci/ μ M/ml	region of elongation, cell wall
seed	2	60	0.1 μ Ci/ μ M/ml	aleurone layer
root	3	30	18 μ Ci/ μ M/ml	meristematic
root	4	30	18 μ Ci/ μ M/ml	stele
root	4	30	18 μ Ci/ μ M/ml	meristematic

^a Specific activity refers to the amounts of S-methyl-L-methionine-¹⁴CH₃ used in the incubation media.

^b Tissue of incorporation determined by presence of silver grains in autoradiograms.

Observations of silver grains within the root tissue suggest that S-methyl-L-methionine is donating a methyl group to the formation of pectic substances within the cell wall. In 1957 Sato and others (7) presented evidence which for the first time showed that methyl esters of pectinic acid may be formed by a transmethylation reaction in higher plants. In this study, the methyl group of methionine was shown to be transferred intact to form pectinic acid methyl esters in radish plants. Further studies by this same group (8) indicated that methionine is not essential for methyl esterification since methionine sulfoxide and S-methyl-L-methionine as well as methionine act as methylating agents for pectin and protopectin in intact oat sections. Jakob and Tal (5) have recently described the incorporation of methyl groups from methionine into pectinic acid in germinating *Vicia faba*.

Conclusion

The results of this study indicate an absorption of S-methyl-L-methionine-¹⁴CH₃, or its methyl group, by the roots of winter wheat seedlings. Absorption rate appears to be greatest within the first 24 hours of incubation, and appears to decrease on longer incubation. Liquid scintillation studies with solubilized tissues indicate incorporation in the seed parts for day 1, 2, and 3 and incorporation in the root and shoot for day 3. Autoradiographic analysis points to uptake in the seed's aleurone layer after 1 and 2 days' germination and in the root after 1, 2, 3, and 4 days' germination, with localization in the meristematic region and the walls of cells in the region of cell elongation.



FIGURE 1. *Autoradiogram of root meristematic tissue (top).*

FIGURE 2. *Autoradiogram of root tissue in the region of cell elongation (bottom).*

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CHEMISTRY

Chairman: EUGENE P. SCHWARTZ, Department of Chemistry,
DePauw University, Greencastle, Indiana 46135

JOHN H. MEISER, Department of Chemistry,
Ball State University, Muncie, Indiana 47306
was elected Chairman for 1976

ABSTRACTS

A Quantum Chemical Study of the Formation of Formaldimine from HCN Via a Radical Mechanism. JOHN A. RICKETTS, Department of Chemistry, DePauw University, Greencastle, Indiana 46135, and NOEL J. FITZPATRICK, Department of Chemistry, University College Dublin, Belfield, Dublin, 4, Ireland.—Geometry optimized ab initio LCAO-SCF-MO calculations using a minimal STO-3G basis set are discussed for the reaction involving HCN and a hydrogen atom. Of the three isomeric species, cis HCNH, trans HCNH, and H_2CN , the calculations predict that the H_2CN radical is thermodynamically preferred. Consequently, H_2CN can serve as a possible precursor of formaldimine, H_2CNH in a prebiotic atmosphere. In addition pertinent kinetic comparisons of the reaction of HCN with a hydrogen atom to form either trans HCNH or H_2CN are made using a simulated reaction pathway.

Reaction of Phenyl Isocyanate with Active Methylene Compounds. LEROY A. MCGREW, Department of Chemistry, Ball State University, Muncie, Indiana 47306.—Phenyl isocyanate undergoes addition of active methylene compounds such as ethyl acetoacetate and 2,4-pentanedione under mild conditions in the presence of a small amount of a tertiary amine. Addition occurs across the nitrogen-carbon double bond of the isocyanate such that the products are 2-(phenylcarbamyl) derivatives of the active methylene compounds. Seven such monoadducts have been prepared, but all attempts to produce diadducts by addition of the remaining acidic hydrogen to a second molecule of isocyanate have failed. Spectral studies suggest that those monoadducts containing at least one acetyl group prefer to be completely enolized with the formation of two intramolecular hydrogen bonds. Methods of preparation, structures and spectra of the monoadducts were discussed.

The Separation and Identification of the Two Forms of Human Adenosine Deaminase. GARY L. DUNNINGTON and PANG F. MA, Department of Chemistry, Ball State University, Muncie, Indiana 47306.—Two different forms of adenosine deaminase have been observed in human tissues: the high molecular weight enzyme (A form) and the low molecular weight enzyme (C form). These two forms of the enzyme are present in various proportions in different tissues. The separation and identification of the two enzyme forms in previous studies were achieved by gel filtration column chromatography, followed by measurements of enzyme activity in the elution fractions. A rapid and efficient method is needed to perform routine analysis of the enzyme form dis-

tribution and to study the inter-relationship of the two enzyme forms. This study shows the applicability of thin-layer gel filtration technique for the separation and identification of the two forms of adenosine deaminase in human tissue extracts.

Syntheses of β -diamines and β -amino alcohols. MARILYN GEHLHAUSEN and J. A. MOSBO, Department of Chemistry, Ball State University, Muncie, Indiana 47306.—New synthetic routes to the preparations of β -diamines and β -amino alcohols have been realized. Excess methylamine combined with an α,β -unsaturated ketone or aldehyde followed by reductive amination employing NaBH_3CN gave β -diamines in up to 40% yield. Thus, from crotonaldehyde N^1,N^3 -dimethyl-1,3-butanediamine was obtained. Similarly, methylamine combined with an α,β -unsaturated ketone or aldehyde followed by reduction with NaBH_4 resulted in the preparation of β -amino alcohols. This reaction with crotonaldehyde produced 3-methylamino-1-butanol. The likelihood of the reaction sequence consisting of initial addition of amine across the double bond followed by reduction of the carbonyl group was investigated.

Determination of the Concentrations of Selected Substances in the Waters of Otter Creek and the Wabash River, Vigo County, Indiana. JOSEPH R. SIEFKER and LARRY D. BROWN, Department of Chemistry, Indiana State University, Terre Haute, Indiana 47809.—The surface waters of Otter Creek and the Wabash River were sampled February-May 1974. The pH of each sample was measured. The concentrations of ammonia, hydrazine, surfactants; and fluoride, chloride, phosphate, nitrate, nitrite, aluminum, copper, iron, manganese, and nickel ions were determined. Maximum, minimum, and average concentrations were calculated.

The Irreversible Binding of Benzylpenicillin to Human Erythrocytes. MADONNA L. TALBERT and EUGENE S. WAGNER, Department of Chemistry, Ball State University, Muncie, Indiana 47306.—Recent studies using a Beckman LS-100C liquid scintillation system have shown that the *in vitro* 9-hour incubation of benzylpenicillin- C^{14} with human blood followed by exhaustive dialysis results in 4.5% irreversible binding of the antibiotic to components of the blood. This finding prompted experiments which measured the relative irreversible binding of benzylpenicillin- C^{14} to the plasma and erythrocyte portions of blood. The distribution of covalently bonded benzylpenicillin- C^{14} was 1.9% (plasma) and 2.6% (erythrocytes). Further studies indicated that of the benzylpenicillin- C^{14} bound to erythrocytes, one half is bound to the cell membrane and one half is bound to the hemoglobin within the erythrocyte. The effect of the covalent bonding of this antibiotic to hemoglobin on the oxygen carrying capacity of hemoglobin has been investigated.

Using Time-Shared Computer Drill and Testing in General Chemistry. STANLEY L. BURDEN and RONALD J. LOSURE, Chemistry Department, Taylor University, Upland, Indiana 46989.—Software has been developed which permits students to drill and take tests specified by the instructor on various types of questions drawn at random from data in the computer. No supervision is required at any point in the drill or testing procedure. A student immediately receives correct answers

for any questions missed, as well as his final score, expressed as a per cent, for all questions attempted during the drill or testing session. The student may specify the number and type of questions in a drill session and drill as he wishes before taking a test for a grade. When the student is ready to take a test for a grade, he specifies this to the computer and then receives a test in which the total number of questions, the number of each type of question, weighting factors, the time limit for the test, and date by which the test must be taken has been previously specified by the instructor. The computer keeps a record of the student's score and his total accumulated connect and CPU time. Since the questions on each student's test are different, a record can also be kept of both the questions and responses for each student's most recent test. Improvement in student test scores has been achieved in addition to highly favorable student evaluations of their experiences.

Chemical Oxygen Demand and Biochemical Oxygen Demand Problems.

ROBERT H. L. HOWE, Tippecanoe Laboratories, Eli Lilly and Co., Lafayette, Indiana 47902.—The problems constantly involved in testing the C.O.D. or B.O.D. of water and waste water samples are explained. The correction of these problems is suggested.

Chemistry and the Revolution.

DONALD J. COOK, DePauw University, Greencastle, Indiana 46135.—The development of modern chemistry and the growth of the United States of America take place in almost the same time span of history. Beginning with the Industrial Revolution in England and the Scientific Revolution in men's thinking in Europe, one can find an interplay with the spirit of political independence in America. Benjamin Franklin, Joseph Priestly, Benjamin Rush and Benjamin Thompson (who became Count Rumford) lived, studied, made scientific discoveries and participated fully in the political revolutions of the late 1700's.

Byproducts of the Darzens Condensation.

CHARLES J. KELLEY, OSMUND T. O. CHAN, LINDA M. ETTESTAD, HAZEL H. SZETO, PACO A. PARATORE, STEPHEN B. STACKHOUSE, and MARVIN CARMACK, Department of Chemistry, Indiana University, Bloomington, Indiana 47401.—In connection with the synthesis of some natural products, we have undertaken an extensive study of the Darzens condensation of 3,4-dioxygenated benzaldehydes with alkyl chloroacetate esters. In addition to the desired 3-aryl glycidic esters, we isolated several byproducts from the condensation under a variety of reaction conditions. The merits of alternative sets of reaction conditions will be discussed in light of the yields of glycidic esters obtained and the quantities of byproducts encountered. While the heretofore reported byproducts in the Darzens condensation result from the reaction of one mole of aldehyde with one mole of chloroacetate, we have obtained a novel byproduct resulting from the combination of the aldehyde with two moles of chloracetate. Physical and chemical data will be presented which establish the structure of the new byproduct as a substituted tetrionic acid. Additionally the mechanism of its formation will be discussed in light of the quite specific reaction conditions required for its production.

Study of the Fluoride Complexes of Tin(II) Using a Fluoride Ion Specific Electrode

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Prior to the development of the fluoride ion specific electrode by Frant and Ross (6) measurements of the stability or formation constants of fluoride complexes were usually made by the "ferri-method" (2, 4, 5) or by polarography and potentiometry (3, 10, 11). The work of Schaap, Davis, and Nebergall (11) was the first reported for the fluoride complexes of tin in aqueous solution. Later, Connick and Paul (3) using a potentiometric technique estimated the formation constant for the addition of the first fluoride ion to tin(II) in aqueous solution.

In a study similar to that to be reported here Hall and Slater (7) used the fluoride ion specific electrode to obtain the formation constants for SnF^+ , SnF_2 , and SnF_3^- . These authors, however, evidently did not take special care to exclude Sn(IV) from their solutions. Such a highly-charged positive ion would have a strong complexing tendency toward the fluoride ion.

Experimental Procedures

Because the crucial part of the present work which differentiates it from the similar work already published (7) is the preparation of the solutions, the experimental procedures will be described in some detail. The apparatus, similar to that described by Tobias (13), was designed to prepare tin(II) perchlorate solutions of known tin(II) concentration, ionic strength, and acidity under an oxygen-free atmosphere. This solution was then titrated potentiometrically at constant temperature with a solution of fluoride ion. A specific fluoride electrode (Model 94-09, Orion Research Inc.) and a commercial calomel electrode were used with a digital voltmeter (Orion Research Ionanalyzer, Model 605) to sense the concentration of uncomplexed fluoride ion during the titration.

All chemicals were of reagent-grade quality. The sodium fluoride was from the J. T. Baker Chemical Company. The sodium perchlorate (0.01% chloride and chlorate) to fix the ionic strength and the perchloric acid (70%, Double Vacuum Distilled, Lead-Free and 0.0001% chloride) were from the G. Frederick Smith Company. The tin metal foil was lead-free. The method of Tobias (13) was used to prepare the tin(II) perchlorate solutions. This procedure involves the reaction of metallic tin with an acid solution of copper(II) perchlorate under nitrogen atmosphere. The copper(II) perchlorate solutions were prepared by dissolving copper(II) oxide in a perchloric acid solution, the acidity of this final solution being determined by passing an aliquot through a cation-exchange column and titrating the total liberated hydrogen-ion content with sodium hydroxide solution. The nitrogen gas used to free

the solutions from oxygen and to maintain an inert atmosphere during the experiment was purified by the method of Meites and Meites (9).

The work reported here was carried out at a constant ionic strength of 3.0 and 25°C. The highest initial pH of the tin(II) perchlorate solution used was about 1.3, this being deemed sufficient to minimize formation of tin(II)-hydroxide complexes (13). Because of the high hydrogen-ion concentration, the formation of HF and HF_2^- had to be taken into consideration using the formation constants for the hydrogen-fluoride system reported by Kleboth (8). The response of the fluoride ion specific electrode to the concentration of free fluoride ion in the solution was checked before and after each experiment, and was found to be in agreement with the literature.

Results

The result for a typical experiment is shown in Figure 1. The ordinate, $\bar{n}$, as used by Bjerrum (1), is defined as the average number of fluoride ion bound to each tin(II) ion:

$$\bar{n} = \frac{\{[\text{F}^-]_{\text{total}} - [\text{F}^-]_{\text{free}} - [\text{HF}] - 2[\text{HF}_2^-]\}}{[\text{Sn}^{2+}]_{\text{total}}} \quad (1)$$

where $[\text{F}^-]_{\text{total}}$: total fluoride ion concentration corrected for dilution

$[\text{F}^-]_{\text{free}}$: free fluoride ion concentration as measured by the ion-specific electrode.

$[\text{Sn}^{2+}]_{\text{total}}$: total stannous ion concentration corrected for dilution.

$[\text{HF}]$ and $[\text{HF}_2^-]$: concentrations of the hydrogen ion/fluoride ion complexes calculated from the stability constants of Kleboth (8).

The presence of three reasonably distinct breaks in the curve of Figure 1 is indicative of the successive formation of the three complexes, SnF^+ ,

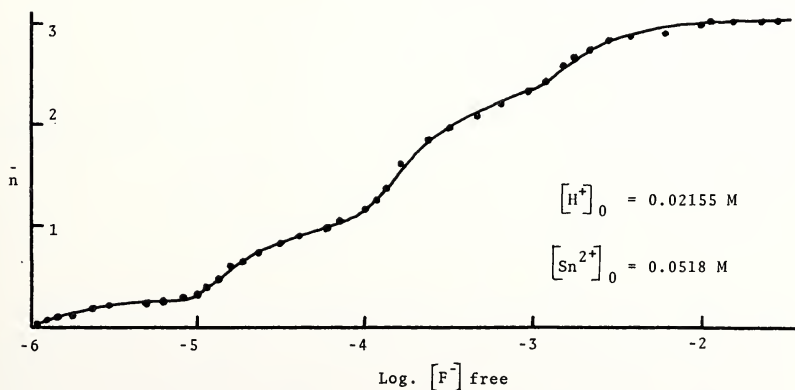


FIGURE 1. Graph of $\bar{n}$ versus logarithm of free fluoride ion concentration for a typical experiment.

SnF_2 , and SnF_3^- , with separated formation constants. Evidence from these experiments was inconclusive concerning the possibility of formation of SnF_4^{2-} .

The determination of the formation constant K_n for the complex SnF_n^{2-n} , where K_n is defined as

$$K_n = \frac{[\text{SnF}_n^{2-n}]}{[\text{SnF}_{n-1}^{3-n}] \cdot [\text{F}^-]} \quad (2)$$

was carried out as follows. Using the data from the region of $\bar{n}$ less than about 2, introduction of equations (2) into equation (1) yields

$$\bar{n} / (1-\bar{n}) [\text{F}^-] = K_1 + \{ (2-\bar{n}) K_1 K_2 [\text{F}^-] \} / (1-\bar{n}) \quad (3)$$

Hence K_1 and K_2 can be obtained from a graph such as Figure 2. Similarly, in a region of fluoride concentration where all three complexes are formed,

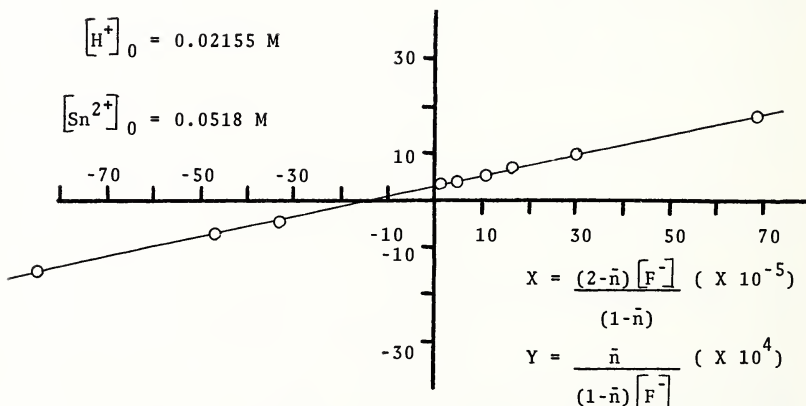


FIGURE 2. Graph for calculation of K_1 and K_2 from data of Figure 1.

$$\frac{\bar{n}}{n} = \frac{[\text{SnF}^+] + 2 [\text{SnF}_2] + 3 [\text{SnF}_3^-]}{[\text{Sn}^{2+}] + [\text{SnF}^+] + [\text{SnF}_2] + [\text{SnF}_3^-]} \quad (4)$$

which after the introduction of equations (2) for each complex yields upon rearrangement

$$\frac{\bar{n} - K_1 (1-\bar{n}) [\text{F}^-]}{(2-\bar{n}) K_1 [\text{F}^-]^2} = K_2 + \frac{(3-\bar{n}) K_2 K_3 [\text{F}^-]}{(2-\bar{n})} \quad (5)$$

A graph to determine K_2 and K_3 from equation (5) is shown in Figure 3. In all cases there were more experimental points than shown on the graphs. Data plotted according to equations (3) and (5) were subjected to least-squares analysis to obtain the formation constants. The results at an ionic strength of 3.0 with sodium perchlorate as the supporting electrolyte and at 25°C were as follows:

$$K_1 = (3.8 \pm 0.1) \times 10^4; K_2 = (5.8 \pm 0.5) \times 10^3; \\ K_3 = (9.4 \pm 0.5) \times 10^2.$$

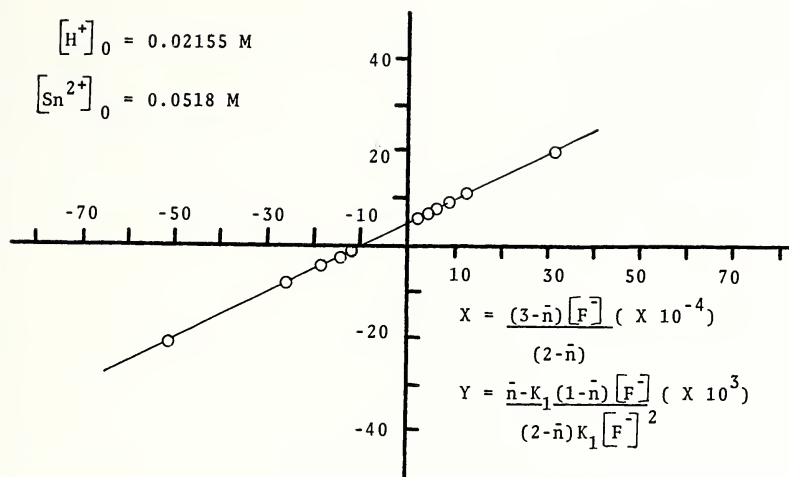


FIGURE 3. Graph for calculation of K_2 and K_3 from data of Figure 1.

Discussion

The results of the present work for the cumulative formation constant $B_3 (= K_1 \times K_2 \times K_3)$ of 2.1×10^{11} is in satisfactory agreement with the value of 9.1×10^{10} reported by Schaap, Davis, and Nebergall (11) who employed a polarographic technique. Moreover, they worked at a different ionic strength and supporting electrolyte. Hall and Slater (7), however, using a fluoride electrode in a work similar to the present one, report a value for B_3 of only 1.77×10^9 at an ionic strength of 0.85.

The logarithm of the formation constants for the halide complexes of various metal ions in aqueous solution has been found empirically to depend linearly on the standard potential of the halogen. Such a relationship is illustrated for several metal ions in Figure 4 for the formation constants for the addition of the first halide ion to the aquo metal ion. The result of the present work (Point V on Figure 4) is close to the expected value based on the long extrapolation from the chloride and bromide results. However, the value of Hall and Slater (7), Point IV on Figure 4, is some two orders of magnitude larger than the expected result, probably because of contamination by the more strongly-coordinating tin(IV) ion.

The results of the present study thus indicate that the formation constant for the addition of the first fluoride ion to the aquo tin(II) ion in aqueous solution is some two orders of magnitude smaller than that value previously reported (7) and confirm a linear relationship between the logarithm of the formation constant and the standard potential for the halogen for tin(II) in aqueous solution.

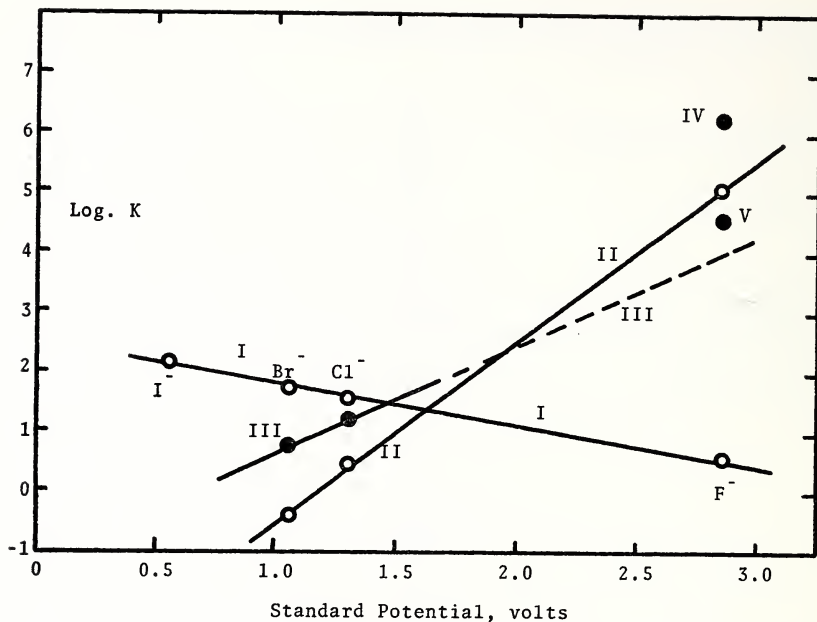


FIGURE 4. Logarithm of formation constant versus standard potential of the halogen, X^-/X_2 . All values at 25°C and at an ionic strength of 3.0 using sodium perchlorate as supporting electrolyte, except where indicated. Data for curves I, II, and III from Reference (12).

Curve I: $Cd^{2+} + X^- = CdX^+$

Curve II: $Fe^{3+} + X^- = FeX^{2+}$

(for clarity curve is displaced downward by 1 unit).

Curve III: $Sn^{2+} + X^- = SnX^+$.

Point IV: Reference (F), ionic strength 0.85.

Point V: Present Work.

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A Rational Analysis of Cooling Water For Material Protection

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West Lafayette, Indiana

Abstract

The chemical and physical properties of certain cooling water are discussed and analyzed. The determination of its saturation pH_s value to evaluate the possible corrosive or scale-forming tendency of the water, before and after chemical treatment of the cooling water is derived. A rational method of using both Langelier and Ryzner approaches is proposed and tested by the author. Some illustrations are given in the paper.

Introduction

In the treatment of cooling water for the protection of piping material or heat-exchange equipment against scale formation or corrosion, two outstanding analytical methods of evaluation have been well recognized^(1,2,3) and are quite useful to water chemists and process engineers. One is the Langelier's Index and the other is the Ryzner's Index.

The basic reasoning is the calculation of the saturation pH value (or pH_s) from the analytical determination of the activity coefficients of the water (K_s and K_2), the calcium ion concentration $[\text{Ca}^{++}]$, the concentration of total alkalinity $[\text{A}] = [\text{OH}^-] + [\text{HCO}_3^-] + [\text{CO}_3^-]$ and the ionic strength coefficient of all the dissolved salts $[\text{S}] = 2.5\sqrt{\mu}/(1 + 5.3\sqrt{\mu} + 5.5\sqrt{\mu})$, according to Larson and Buswell⁽²⁾. The value of pH_s can be written in the following simplified form:

$$\text{pH}_s = 9.30 + \text{S} + \log \frac{K_s}{K_2} - \log [\text{Ca}^{++}] - \log [\text{A}] \quad (1)$$

or, in a simpler form,

$$\text{pH}_s = 9.30 + \text{A} + \text{B} - \text{C} - \text{D} \quad (2)$$

where $\text{A} = \text{S}$, $\text{B} = \log \frac{K_s}{K_2}$, $\text{C} = \log [\text{Ca}^{++}]$ and $\text{D} = \log [\text{A}]$

B, the activity coefficient ratio term is greatly governed by the temperature. These factors have been studied by Larson, et al.^(2,3) and they can be obtained from Figure One⁽⁴⁾.

The Langelier's Saturation Index is written as:

$$\text{L.I.} = \text{pH} - \text{pH}_s \quad (3)$$

where pH_s is described in equation (1) and pH is the actual value measured of the water.

A negative (—) value of L.I. indicates the *presence* and a positive (+) of L.I. indicates the *deficiency* of excess dissolved CO_2 in the water. A negative value of L.I. thus also indicates the degree of corrosive tendency of the water and a positive value indicates the scaling tendency⁽¹⁾.

The Stability Index as advanced by Ryzner is described as:

$$\text{R.I.} = 2\text{pH}_s - \text{pH} \quad (4)$$

A water having a value of R.I. of less than 6.0 is very definitely scale-forming, and that having a value of R.I. of higher than 7.0 is corrosive in nature⁽²⁾.

With the consolidation of both indices, Howe⁽⁴⁾ has developed a simple rational method of interpretation through simple orientation of the two systems and to evaluate the water quality by the joint relationship of R.I., L.I., and pH of the water:

$$\text{R.I.} = \text{pH} - 2 \text{ L.I.} \quad (5)$$

$$\text{and } \text{pH} = \text{R.I.} + 2 \text{ L.I.} \quad (6)$$

Equations (5) and (6) explain that the Langelier's Saturation Index, pH and the Ryzner's Stability Index are dependent on each other, in terms of their meanings. It also indicates that the pH of the stabilized water should be equal to the sum of Ryzner's Index plus two (2) times of Langelier's Index! If the pH is increased, the pH_s also increases in order to maintain the same L.I. or R.I. values of the water, other factors unchanged. In the meantime, when the pH is lowered, the pH_s is also lowered for the same L.I. or R.I. values of the water with other factors unchanged.

To produce a "stabilized" water in order to minimize its corrosion and scaling tendency on carbon steel, wrought iron, or cast iron, etc., it is desirable to maintain the L.I. within 0 to 0.5, and the R.I. between 7.0 and 8.0. Using a specific water of which the properties are given in Table One, a group of control graphs of this water to be used for cooling are developed for all illustrations. It must be known that any chemical treatment to change pH_s would cause changes in the chemical factors responsible for the pH_s value.

TABLE 1. *The analytical data of a cooling water.*

	Sample				Average		
	1	2	3	4	Av.		Term
Temp °C	40	60	50	50	50		
Temp °F	---	---	---	---	(122)	B	1.50
Total Diss. Solids, mg/2	380	380	405	400	391	A	0.16
Ca Hardness, mg/1	277	332	274	227	278	C	2.04
Total Diss. Solids, mg/1 (CaCO ₃)	258	268	268	247	280	D	2.40
pH	7.85	7.95	8.01	7.81	7.91	--	---

The values A, B, C, and D are obtained from Figure 1 and the pH_s value can thus be calculated. Also, the relationship of pH, L.I., R.I. at different pH values is illustrated in Figure 2.

$$\text{pH}_s = 9.30 + (1.5 + 0.16) - (2.04 + 2.40) = 6.52$$

At pH = 7.91, we have

$$\text{L.I.} = 7.91 - 6.52 = +1.39$$

$$\text{R.I.} = 2 \times 6.52 - 7.91 = +5.13$$

From Figure 2 it can be seen that the water is quite scaling even at a temperature slightly higher than 60°F. In order to protect the piping

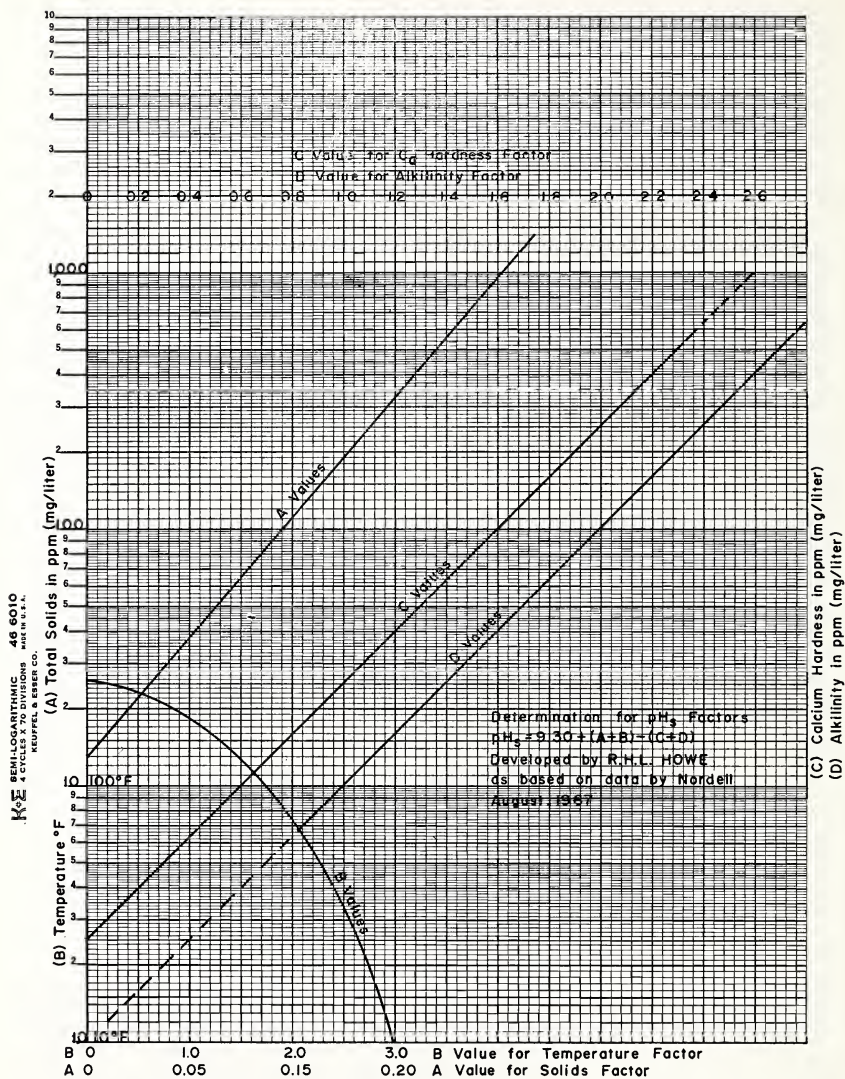
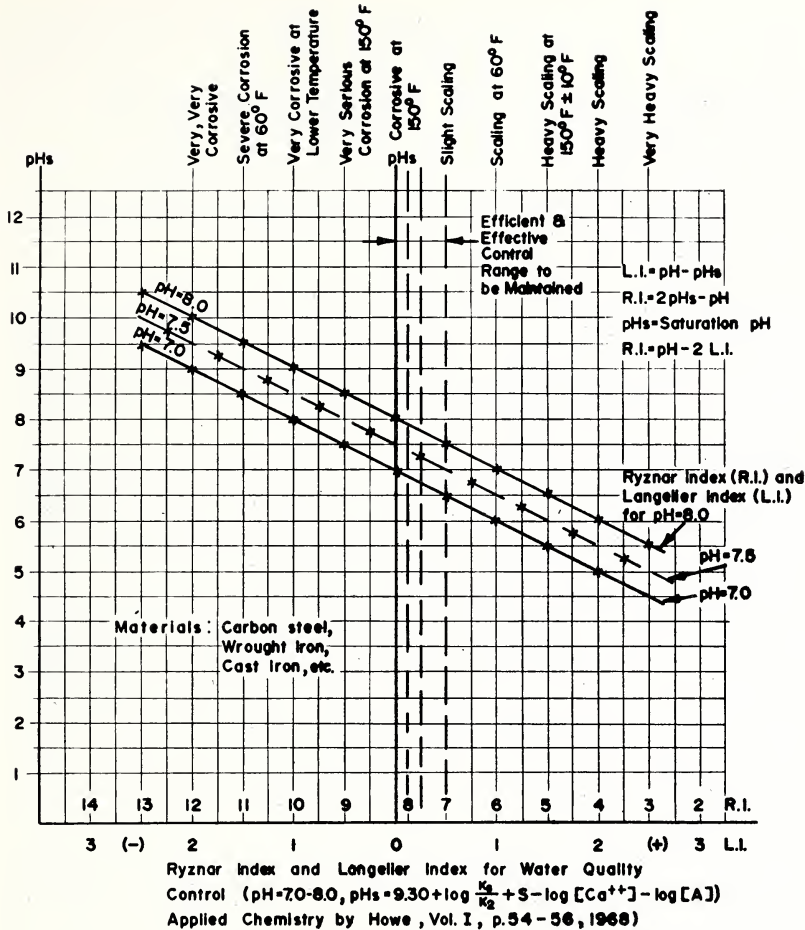


FIGURE 1.

or equipment, it is obvious that water needs treatment for its stabilization. Now, the water mentioned in Table One has been treated with 5.0 ppm of polyphosphates for moderate cooling (maximum temperature 120°F). For high temperature cooling (maximum 212°F), additional treatment with a preparation of combined organic-inorganic-dispensant-stabilizers (50 ppm) has to be used. The analytical results of treated water are in Table Two.



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FIGURE 2.

TABLE 2. *Treated water analysis.*

		Term	
Temperature	122°F	B	1.50
Total Dissolved Solids, mg/l	467	A	0.17
Ca Hardness, mg/l	279	C	2.05
Total Alkalinity	80	D	1.90
pH	7.1		
$\text{pH}_s = 9.30 + (1.50 + 0.17) - (2.05 + 1.90) = 9.30 + 1.67 - 3.95 = 7.02$			
$\text{L.I.} = 7.2 - 7.02 = +0.18$			
$\text{R.I.} = 2 \times 7.02 - 7.02 = +6.84$			
$\text{L.I.} = \frac{7.2 - 6.84}{2} = \frac{0.36}{2} = +0.18$			

From these numbers to fit into Figure 2, it can be noted that the water has now only a slightly scaling tendency, and it is well within the regime of "effective control."

Indeed, it is hoped that this simple rational approach may assist chemists and/or engineers in their daily endeavor of protecting materials and equipment against damages by corrosion or scale formation due to improper or inadequate water treatment, either internally or externally!

The author wishes to acknowledge his appreciation of many engineers and chemists for their cooperation in supplying data of routine or special water treatment tests and results. He particularly dedicates this report to the cooperating engineers and chemists at Tippecanoe Laboratories, Clinton Laboratories, Greenfield Laboratories, and other facilities of Eli Lilly and Company.

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ECOLOGY

Chairman: WILLIAM B. CRANKSHAW, Department of Biology,
Ball State University, Muncie, Indiana 47306

JOHN O. WHITAKER, Jr., Department of Life Sciences,
Indiana State University, Terre Haute, Indiana 47803
was elected Chairman for 1976

ABSTRACTS

The Reduction of Fecal Coliform by Biological Oxidation. ROBERT H. L. HOWE, West Lafayette, Indiana 47906.—The reduction of fecal coliform bacteria by the proper function and operation of several aerobic biological treatment processes is reviewed. Some data are presented, and points of significance in achieving the reduction are discussed.

A Rapid Technique for Instar Identification of Lake Michigan Copepods. BYRON G. TORKE, Biology Department, Ball State University, Muncie, Indiana 47306.—A method for identification with a dissecting microscope of the naupliar instars of copepod crustaceans based on body shape and the successive appearance of appendages is presented. Copepodid instars are identified on the basis of appendage and urosome segment numbers. The relevance of instar identification to the determination of growth rates in natural populations and to estimation of secondary production is discussed.

Phytoplankton Population Dynamics of the In-Shore Waters of Southern Lake Michigan Near Michigan City, Indiana from June, 1973 to May, 1974. THOMAS E. LAUER and THOMAS S. MCCOMISH, Biology Department, Ball State University, Muncie, Indiana 47306.—Monthly whole-water phytoplankton samples were collected in Lake Michigan near Michigan City, Indiana from June, 1973 to May, 1974 on three transects at eight stations with depths ranging from 5 to 18m.

A total of 226 taxa were identified in composite samples. The diatoms *Fragilaria crotonensis* (16%), *Thalassiosira fluviatilis* (11%), and *Tabellaria fenestrata* (9%) numerically dominated the Lake Michigan phytoplankton assemblage during the study period.

Species encountered in this study indicate continued succession of Lake Michigan phytoplankton and eutrophication of the southern near-shore water.

A Survey Of Chlorinated Hydrocarbon Insecticides In Fishes From Streams Of Central Indiana. MARY GOSSARD, DR. DAVID W. OSGOOD, Department of Biology, Butler University, Indianapolis, Indiana 46208.—Twenty-six fish from four stations in Central Indiana were collected in the summer and fall of 1974 and analyzed for aldrin, dieldrin, heptachlor, heptachlor epoxide and o,p-DDT. Dieldrin was found in all fish analyzed. In two of them, levels exceeded the action guidelines set by the Environmental Protection Agency. Generally higher levels of all pesticides analyzed were found in fishes from the Whitewater River in

Richmond than from other locations. Additional monitoring of pesticide levels in fishes from streams in Indiana should be undertaken, the sources identified and controlled.

Preliminary Report On The Status Of A Rare Shiner (*Notropis ardens lythrurus*) In The Little Blue River, Crawford County, Indiana. RONALD RIDENOUR, Indiana Department of Natural Resources and H. E. MC-REYNOLDS, U.S. Forest Service.—In Indiana, the Ohio rosefin shiner (*Notropis ardens lythrurus*) occurs only in a few southeastern and south central tributaries of the Ohio River. It has been considered to be allopatric to a related species (*Notropis umbratilis cyanocephalus*), the northern redfin shiner. Specimens of *N. ardens lythrurus* were taken in 1942 by Gerking (1945) at one locality in the Little Blue River. Preliminary efforts of this study have not disclosed the Ohio rosefin shiner in the mainstem of Little Blue River. However, the tributaries have not yet been sampled, and the study will continue next year.

Changes in Reproductive Effort Among Dominant Herbaceous Dicots in Early Old Field Succession. ALAN O. PRIEBE and DONALD R. WHITEHEAD, Indiana University, Bloomington, Indiana 47401.—Changes in community structure and reproductive effort were studied as part of a long term investigation of old field succession. For four years after the onset of succession, all species of reproductively active dominant herbs were sampled biweekly, individuals were separated into tissue types, and dry weights calculated to determine reproductive effort. Results to date show: Mean reproductive effort drops significantly from one year to the next for each of the four years. Within each year subsequent to the first, there appear to be three peaks for reproductive effort in the system, one each in spring, early summer and late summer. The spring peak is seen to increase progressively from one year to the next.

Four decades of vegetational change in Mount Rainier National Park, a photo-comparison study. ALTON A. LINDSEY, Department of Biological Sciences, Purdue University.—About 450 35-mm photographs were taken during 3 summers work in this park starting in 1933. Many of the sites were located and rephotographed during July-September, 1974. Comparison of the resulting photo-pairs, projected side by side on two screens, is the basis of this presentation.

Interpretations of the landscape and vegetational changes involve recovery from forest fires, revegetation of moraines, bedrock, and flood plain surfaces, disappearance of subalpine ponds, invasion of mountain meadows by *Abies lasiocarpa*, succession in avalanche chutes, degradation of dead standing and down timber, and seasonal advance.

Trace Elements in Natural Waters of Grant and Surrounding Counties. M. E. TAVENNER, D. KLOPFENSTEIN and E. NUSSBAUM, Mississinewa High School, Gas City, Indiana 46983, Taylor University, Upland, Indiana 46989.—Natural water samplings from the headwaters and from the first large urban areas along the three rivers—the Salamonie, Mississinewa and Wabash are analyzed for selected elements. In these

river water studies the geologic nature of the river beds are reflected in the metal ion content of the waters, along with the metal ions that might enter the rivers from industrial, agricultural and domestic sources. Our investigations included analysis for Ca^{++} , Mg^{++} , Fe^{+++} , Mn^{++} , Cu^{++} , Na^{+} and K^{+} . (Of these, only Na^{+} and Ca^{++} are analyzed on a regular basis by the Indiana Stream Pollution Control Board.) The concentrations of Na^{+} and K^{+} were determined by flame photometry. Other ions were analyzed by means of atomic absorption spectrophotometry.

Average concentrations of ions (ppm) in the water samples from the headwaters of the three rivers range from 54-120 of Ca^{++} , 18-32 of Mg^{++} , 0.20-6.55 of Fe^{+++} , 0.033-0.80 of Mn^{++} , 0.00-0.05 of Cu^{++} , 9-19 of Na^{+} , and 2.7-5.7 of K^{+} .

Flow rates of the rivers affected certain concentrations. Ca^{++} was nearly twice as abundant during dry weather, while iron content, in some instances, increased by a factor of 30 during the wet period. The magnesium content, however, remained unchanged.

In addition to the river water analyses, four deep wells were sampled. The Na^{+} was nearly 3 times as high at a well 2 miles from a highway department salt storage area as at other wells.

Hoot Woods: Composition and Tree Growth during 1965-1975. D. BRIAN ABRELL and MARION T. JACKSON, Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809.—In 1975, a 10-year resurvey was made of the 10.87-acre portion of the 64-acre old growth beech-maple stand that was mapped at a 33:1 scale in 1965. Tree-by-tree comparisons were made for changes in growth, accessions and mortality. Patterns of accessions and mortalities were checked for randomness.

Beech (*Fagus grandifolia* Ehrh.) remained the most important species, but declined in density, basal area and importance. The co-dominant sugar maple (*Acer saccharum* Marsh.) had corresponding increases. Log density-size class plots revealed density decreases in middle size classes and increases in larger trees. Accessions and mortalities tend toward clumped distribution.

Comparison of Vigo County, Indiana, Vegetation: Presettlement (1814) versus Contemporary (1974). F. ELLEN OLIVER DONSELMAN, Department of Health, Dayton, Ohio 45402, and MARION T. JACKSON, Indiana State University, Terre Haute, Indiana 47809.—Vegetation data for four physiographic units (floodplain, terrace, upland slope and upland flats) of Vigo County, Indiana, were obtained from the General Lands Office Survey Records of 1814 and by sampling 16 little-disturbed contemporary stands.

About 22% of the county was originally prairie, mostly located on the Wabash River terrace. The oak-hickory forests of the terrace have become more xeric in the past 160 years. The greatest changes in composition occurred on the Wabash River floodplain, where hydrophytic species increased 46% in importance, with corresponding declines for xeric and mesic species. Clearing for agriculture, plus increased

frequencies and duration of flooding may be responsible. Mesic species increased in upland forests, with xeric species declining.

No presettlement forest unit was mapped as beech-maple. Upland slopes were classed as mixed woods; oak-hickory predominated on the terrace and upland flats.

Composition of the Presettlement Forests of the "Unglaciaded" Jo Daviess Hills of Northwestern, Illinois. JANE WEATHERHOLT FINNEY, Box 63, Centerton, Indiana 46116, and MARION T. JACKSON, Indiana State University, Terre Haute, Indiana 47809.—Forest composition was determined for the rugged "driftless" region of extreme northwestern Illinois by analysis of the General Land Office Survey Records of 1842.

Upland slope forests (86% of the area), containing 21 species, were 97% oak-hickory, with white oak, bur oak and black oak being the leading dominants. Ravine forests (7% of area) had more mesic species among the 19 total, with bur oak, elm, black oak, basswood and white oak the dominants. Terraces (2% of the area) contained only 8 species and were 95% oak-hickory. Mississippi River floodplain forests (5% of area), containing 13 species, were dominated by such hydrophytic species as soft maple, elm, river birch, ash and black willow.

These findings suggest that the original vegetation of the Jo Daviess Hills was predominantly oak-hickory and should not be typed maple-basswood as traditionally mapped.

Ecological Reactions. DONALD E. MILLER, Department of Biology, Ball State University, Muncie, Indiana 47306.—The term reaction refers to the influence exerted by an organism or a community of organisms upon the habitat. Ecologists recognize the importance of such influences but have been reluctant to use the term reaction. It is desirable to have a word or short expression to designate this concept. No one, to date, has suggested a better word than reaction. It is recommended that ecologists use the term reaction along with the terms coaction and response.

Comparison of Fish Impingement at the Palisades Nuclear Power Plant for Once-Through and Closed Cycle Cooling

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Abstract

Two studies of fish impingement were conducted at the Palisades Nuclear Power Plant. The first (May 16, 1972 to October 25, 1973) during once-through-cooling and a second (March 10, 1974 to March 29, 1975) during closed cycle cooling using mechanical draft cooling towers.

The Palisades facility, which has an ultimate electrical output up to 821 megawatts, began operations in early 1972. The cooling water intake is submerged 1006 meters offshore at a minimum depth of about 7.6 meters. The heated discharge enters the lake directly at the shoreline. The total flow rate was about 30686 liters/sec during once-through-cooling and 4644.5 liters/sec during closed cycle cooling.

From May 16, 1972 to October 25, 1973 daily records showed a total of 651,712 fish weighing 19842.2 kilograms were impinged on the traveling screens. Of these totals, alewife (*Alosa pseudoharengus*), slimy sculpin (*Cottus cognathus*), spottail shiner (*Notropis hudsonius*), and perch (*Percha flavescens*) made up 58.6, 27.5, 7.2, and 4.4 percent, respectively, of the total number. Coregonoids and salmonids, and smelt, *Osmerus mordax* made up 0.2 and 1.0 percent of the total respectively.

The fish appeared seasonally on the screens with none of the 37 recorded species being collected regularly. In addition, 4,768 crayfish, *Orconectes propinquis* were counted, mostly during late spring and early summer.

Results from the March 10, 1974 to March 29, 1975 study showed 2724 individuals weighing 25 kg were impinged during 111 screen counts which represented 31.3 percent of the total number of hours the screens were operated. Slimy sculpin and alewife made up 85.8 and 11.4 percent respectively of the total, with seven other species comprising the additional 2.8 percent. Extrapolation of the data (based upon weekly screen counts) showed that potentially 7488 fish weighing 68 kg could have been impinged. An additional 8096 crayfish were impinged and extrapolation show that potentially 10,218 could have been impinged.

The change from once-through-cooling to closed cycle cooling resulted in a significant decrease in the total number, weight, and number of fish species impinged at the Palisades Plant resulting in a reduction of biomass removed from the inshore area Lake Michigan near South Haven.

Introduction

This paper compares the results of fish impingement rates at the Palisades Nuclear Generating Plant. The data were collected for 75 weeks (May 16, 1972 to October 25, 1973) during once-through-cooling as part of a total environmental study (Consumers Power Co., 1975) and for 54 weeks (March 10, 1974 to March 29, 1975) during closed-cycle-cooling with mechanical draft cooling towers.

Description of the Plant and Study Area

The plant is located in Van Buren County on a 197 hectare site on the eastern shore of Lake Michigan in the southwestern part of Mich-

igan. The site is approximately 7 kilometers south of South Haven and 26 kilometers north of Benton Harbor and St. Joseph.

The Palisades facility, has rated capacity of about 700 megawatts electric (MWe) with an ultimate electrical output up to 821 MWe. The plant utilized a pressurized water nuclear reactor system and the steam was condensed by means of a once-through condenser cooling system using Lake Michigan water to dissipate the waste heat. The waste heat at rated capacity increased the cooling water temperature a maximum of 19°C above ambient at the intake. Cooling water is taken from Lake Michigan through an intake crib located 6.1 meters below the lake's surface, 1.8 meters from the lake bottom, and 1000 meters from the shoreline. The crib is a 17.4 meters wide, 17.4 meters long, 3.7 meters high box with a steel plate for its top and 0.05 meter vertical bars spaced 0.25 meters apart around the sides. Water flows horizontally between the vertical bars at a measured velocity of 0.21-0.29 m/sec and subsequently is diverted to a 3.4 meter intake pipe rated at 2.9 m/sec at full-flow conditions.

The heated discharge entered Lake Michigan directly at the shoreline. The total flow rate through the once-through cooling system was about 30686 liters/sec. This cooling system was used until completion of mechanical draft evaporative cooling towers in early 1974. These towers converted the circulating water system to essentially closed cycle cooling with a 98.5 liters/sec blowdown discharged at the shoreline to the lake. This blowdown, when diluted by 4546 liters/sec will be no more than 3°C above ambient lake temperature.

Methods

The plant intake water flows through 0.95 cm mesh traveling screens. During the 1972-73 study the screens were usually run twice per 24-hour period, except during heavy runs of fish when they were run continuously. All fish impinged were sluiced into a collection basket, identified, counted, and weighed on a daily basis. During the 1974-75 study, 111 screen counts were conducted during the 54 weeks. A screen count entailed running the screens until all impinged fish had been sluiced off into the basket. The time span between successive runs was documented to make the screen counts a representative as possible of variations in diurnal and nocturnal fish movement. These data were then extrapolated for each week of the survey period and a potential number of fish impinged was calculated based upon the percent of time covered between counts for each week.

Fish Impingement During Closed Cycle Cooling

Table 2 shows the actual and potential number and weight of the fish impinged from March 10, 1974 to March 29, 1975. Nine species totaling 2724 individuals, weighing 25 kg were collected in 111 screen counts covering a total of 2839 hours between screen runs at the plant. These counts covered 31.3 percent of the total time fish could have been impinged.

Slimy sculpin and alewife comprised 85.8 and 11.4 percent of the total respectively. The other 7 species combined made up the additional 2.8 percent with spottail shiners and smelt being the next most frequently collected. If we extrapolate the actual number of fish collected by the percent time covered per week (assuming the rate and numbers of fish impinged would be constant over the time intervals not covered) a potential 7,488 fish could have been impinged.

The actual weight of the fish impinged was 25 kg. If this weight is extrapolated it would show 68 kg of fish could have potentially been impinged for the 54 weeks.

In addition to the fish being impinged, a single species of crayfish, *Orconectes propinquis* was also impinged during the summer months (June to September). During the May 16, 1972 to October 25, 1973 study 4768 crayfish were impinged, as compared to an actual number of 8096 and a potential number of 10,218 impinged during the latter study. Scuba diving observations near the intake showed this species inhabited the area surrounding the intake crib, indicating the intake crib and associated rip-rap act as a habitat for the crayfish during March through October. The majority of these crayfish were sluiced off alive and in good condition.

Fish Impingement During Once-Through Cooling

Table 1 shows the total number, weight and period of greatest impingement from May 16, 1972 to October 25, 1973. A total of 651,712 fish weighing 19842.2 kilograms were impinged on the screens. Of this total, four species of fish, alewife, slimy sculpin, spottail shiner, and perch made up 58.6, 27.5, 7.2, and 4.2 percent respectively of the total number of fish, and 62.8, 5.8, 4.3, and 18.1 respectively of the total weight of fish. Longnose sucker, burbot, and white sucker made up 3.7, 1.7, and 1.4 percent respectively of the total weight of fish although combined they made up less than .003 percent of the total number of fish. The most numerous groups of fish appeared in the vicinity of the plant intake on a seasonal basis.

Except for perch, the number of game fish impinged was small in comparison to nongame fish in the collections. The salmonids (steelhead, coho, chinook, lake trout, and brown trout) totaled 139 individuals weighing 72.6 kilograms while coregonids (cisco, lake whitefish, round whitefish and bloaters) totaled 551 individuals, weighing 55.8 kilograms. The majority of coregonids were impinged on just a few days and these usually followed an upwelling in the lake. The only other game fish were smelt, totaling 7565 individuals, weighing 193.7 kilograms and northern pike totaling 18 individuals, weighing 6.8 kilograms.

The condition of the impinged fish varied from excellent to battered, dead or decomposed. The majority (over 50 percent) of the fish showed signs of physical damage including descaling, hemorrhaging, cuts, and gouges. It is doubtful that many of the fish in this condition could have survived if put back into the lake, considering the possibility of increased infection and predation pressures.

TABLE 1. Total number of fish collected daily from traveling screens at the Palisades Nuclear Power Plant from May 16, 1972 to October 25, 1973.

Species	Total Number	% Total Number	Total Weight (Kilograms)	% Total Weight	Period of Greatest Impingement
Alewife—young	339,807	52.1	12,464.0	62.8	October, 1972; October, 1973
—adult	42,565	6.5			April, 1973
Slimy Sculpin	178,376	27.5	1,146.0	5.8	March-April-May
Spottail Shiner	46,897	7.2	854.9	4.3	October-April, 1973;* Dec. (esp.)
Perch—young	27,330	4.2	3,589.6	18.1	October-December, esp. Dec., 1972
—adult	1,084	*			May-June, 1972, 1973
Smelt—adult	6,691	*	193.7	1	April-May, 1973
—young	874	*			June-August, 1973
Trout-perch	3,485	*	62.6	*	April-June, 1973; May, 1972
Longnose Sucker	1,294	*	732.4	3.7	June, 1973
Bloater	519	*	46.3	*	May-August, 1972 and 1973
Burbot	493	*	344.7	1.7	December-March, 1973
Nine-spine Stickleback	409	*	2.3	*	April-June, 1972, 1973
White Sucker	395	*	283.4	1.4	December-January, 1973
Channel Catfish	167	*	20.0	*	December-January, 1973
Lake Trout	81	*	41.3	*	January-March, 1973
Black Bullhead	76	*	3.2	*	April-June, 1972
Chinook Salmon	28	*	12.2	*	June-July, 1973 (young)
Lake Whitefish	28	*	7.7	*	August, 1973

[illegible]

* Indicates less than one percent of the total.

Results and Discussion

The change from a once-through-cooling system to an essentially closed-cycle cooling system has significantly reduced the total number, weight and numbers of fish species impinged on the traveling screens at the Palisades Nuclear Power Plant. Based upon the potential number of fish impinged the reduction has been over 95 percent.

In both studies the largest number of fish by species were alewife and slimy sculpin, neither of which is considered economically important to the sport or commercial fishing industry. Both are considered forage fish, especially to the salmon and lake trout which supply the majority of the sport fishing in this area of the lake.

Without knowing the magnitude of the lake-wide populations it is difficult to say if this reduction in biomass is significant to the lake, but as indicated by the data closed-cycle cooling impinges fewer fish than once-through cooling.

TABLE 2. *Actual and potential number of fish impinged on the traveling screens at the Palisades Nuclear Power Plant from March 10, 1974 to March 29, 1975.*

Species	Actual Total Number	% Total Number	Potential Total Number	Actual Total Weight (kg)	% Total Weight	Potential Total Weight (kg)
Slimy Sculpin	2342	85.8	6510	11.6	46.6	31.4
Alewife: young	2	*	6			
adult	312	11.4	787	12.3	49.3	33.4
Spottail shiner	17	*	49	0.34	*	1.0
Smelt: young	9	*	27			
adult	6	*	17	0.23	*	0.7
Perch: young	9	*	26			
adult	4	*	12	0.23	*	0.7
Ninespine stickleback	9	*	24			
Trout perch	7	*	18	0.11	*	0.3
Gizzard shad	5	*	13	0.11	*	0.3
Channel catfish	2	*	5	0.06	*	0.2
Totals	2724		7488	25	*	68.0

* Indicates less than one percent of total.

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Notes on the Biology of the Lake Trout and Other Selected Salmonidae in Indiana Waters of Lake Michigan

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Abstract

Lake trout (*Salvelinus namaycush*), coho salmon (*Oncorhynchus kisutch*), and chinook salmon (*Oncorhynchus tshawytscha*) were collected with gill nets in Indiana waters of Lake Michigan from April to November 1970. Collection sites were mainly in the vicinity of Michigan City, Burns Ditch, and Gary at depths ranging from 5 to 18 m.

The mean calculated total lengths of known-age reintroduced lake trout for the first through fifth years of age revealed faster growth than reported for original native Lake Michigan lake trout. Genetic differences in the stocked lake trout strain and the abundant alewife (*Alosa pseudoharengus*) forage base may be implicated.

Sea lamprey (*Petromyzon marinus*) scars or wounds were found on 25% of the lake trout captured and were restricted to fish 50 cm or greater in total length. No scars or wounds were noted on coho salmon or chinook salmon.

Alewives were the major food consumed by lake trout (93 percent volume), coho salmon (97 percent volume) and chinook salmon (100 percent volume). Lake trout smaller than 58 cm total length tended to consume small alewives (70-187 mm) while larger lake trout ate large alewives (126-182 mm) exclusively.

Introduction

Drastic changes in the community structure of Lake Michigan have occurred since 1900. These changes have been brought about by numerous factors (17). The sea lamprey (*Petromyzon marinus*) was a major factor because it decimated the native lake trout (*Salvelinus namaycush*) to near extinction by the mid 1950's (8). The absence of the lake trout as a top carnivore allowed a dramatic population explosion of the alewife (*Alosa pseudoharengus*) between 1949 and the late 1960's (2). Recent large-scale reintroductions of lake trout and introductions of Pacific salmonids have met with success in utilization of the huge alewife forage base and improvement of the trophic imbalance.

The main objective of this research is to provide insight to aspects of the biology of the reintroduced lake trout in the southern basin of Lake Michigan including growth, lamprey scarring, and food habits. A secondary objective is to elucidate the food habits of coho salmon (*Oncorhynchus kisutch*) and chinook salmon (*Oncorhynchus tshawytscha*). This information will be useful in understanding current Lake Michigan fish community dynamics.

Methods and Materials

Salmonids were collected from April 30 to November 18, 1970 in Indiana waters of Lake Michigan. Collection sites were mainly in the vicinity of Michigan City, Burns Ditch, and Gary at depths ranging from 5 to 18 m. Miller (16) describes the sample areas in detail.

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Fish were captured with 366 m long by 1.5 m deep white nylon gill nets composed of four 91.5 m panels of 6, 8, 10, and 13 cm stretch mesh netting. Nets were usually set on the bottom and lifted 24 hr. later. All salmonids were removed from nets and taken to shore. After return to shore, usually within 1 to 2 hr. after lifting nets, fish were identified, weighed to the nearest 0.03 kg, measured in total length to the nearest 0.25 cm, sexed and examined for fin clips and sea lamprey scars or wounds. A scale sample was collected from each fish in the area above the lateral line and below the dorsal fin. Finally, the stomach was removed by cutting at the esophagus and the pyloric valve, wrapped in cheesecloth, labeled and preserved in about 10% formalin.

In the laboratory, each stomach was flushed into a white enamel pan and contents were allowed to settle for about one hour. Obvious food items were removed for immediate identification and measurement. The remaining contents were examined at 6 to 16 X magnification and additional food items were identified and counted. The volume of individual items in a stomach were estimated either directly by water displacement of intact specimens or indirectly by measurement of specimens and calculation of volume based on their form. Miller (16) describes methods of stomach analysis in detail.

Lake trout scales for age analysis were cleaned with detergent, rinsed with water, placed into Diaphane on a glass slide, covered with a cover slip and allowed to dry for about one week. Prepared scales were projected onto a white background at 85 X with a Baush and Lomb Tri-Simplex Microprojector. Annuli on scales were located on the basis of criteria presented by Cable (4). The number of annuli found was checked against the known age of the fish from fin clip records. Calculated total lengths at annulus formation were computed by the direct proportion formula: $S_n/S_c = L_n/L_c$ where S_c and L_c are observed scale length and total length at capture and S_n and L_n are scale length and total length at annulus formation (5). The body-scale relationship was computed by the formula $TL = a + bSc$ where TL is total length and Sc is the anterior scale radius. The length-weight relationship was computed from the formula $\log W = \log a + n \log L$ where W is weight in kilograms and L is total length in centimeters (11).

Results and Discussion

A total of 69 known-age lake trout, captured between May 1 and November 18, 1970, were used for age and growth analysis. Since the analysis is based on known-age fish having specific fin clips depending on planting date and site, the information is known to be reliable. Therefore, while this is a minimal number of fish for age and growth interpretation it will provide useful preliminary information on the species.

The body-scale relationship of the stocked lake trout is expressed by the formula $TL = 14.5397 + 0.3199 Sc$ ($r = 0.771$) where TL is total length in centimeters and Sc is anterior scale radius in millimeters. The intercept on the determinate axis (14.5) was not used to correct for total length at scale formation in back calculations. The body-scale

relationship results demonstrate that proportionality exists between body length and scale length for the sample fish.

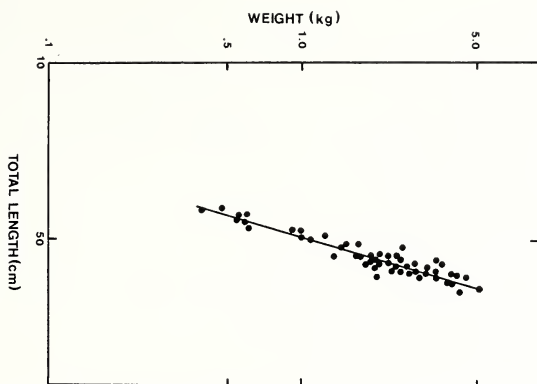


FIGURE 1. Length-weight relationship of 69 lake trout collected in Indiana waters of Lake Michigan in 1970.

The length-weight relationship for the stocked lake trout is expressed by the formula $\log W = -12.4248 + 3.2057 \log TL$ ($r = 0.934$) (Fig. 1). These results are similar to findings by Cable (4) who reported the length-weight relationship of 1,319 native Lake Michigan lake trout as $\log W = -5.391 + 3.1125 \log TL$. The intercept values of the two regression equations vary slightly but the slopes are similar. These results show the reintroduced lake trout are slightly heavier at a given length than the native lake trout.

Scales from four lake trout captured May 1 revealed only two with annuli formed for the current year. Only one specimen captured after July 1 had not formed an annulus. Annulus formation appears to occur between May and the end of June in Indiana waters. These results are in general agreement with Cable (4) who reported annulus formation occurred mainly between May and August in native Lake Michigan lake trout with the 50% level being reached in mid June.

The mean calculated total length and annual growth of stocked lake trout captured in Indiana waters of Lake Michigan in 1970 (Table 1) was greater than reported for native Lake Michigan lake trout (4) (Table 2). Mean calculated total lengths for the first through fifth years of age were 13.9, 26.4, 40.5, 52.1, and 60.8 cm which agreed well with total lengths derived from summation of mean increments of growth. The mean calculated total length ranges of native Lake Michigan lake trout for the first through fifth years of age, summarized from Van Oosten (18), Cable (4), and Van Oosten and Eschmeyer (20) are as follows: 8.4-15.0, 18.0-22.1, 25.7-30.2, 30.7-39.1, and 35.6-46.7 cm (Table 2). Cable (4) reported mean calculated total lengths of 1,319 native Lake Michigan lake trout for the first through fifth years of age were 15.0, 22.1, 28.4, 34.5, and 39.4 cm.

The growth of reintroduced lake trout in Indiana waters of Lake Michigan, based on the 1970 collection, is considerably greater than

TABLE 1. Mean calculated total length with increments of annual growth (parenthesis) for lake trout collected in Indiana waters of Lake Michigan in 1970.

Year Class	Age Group	No.	Mean Size at Capture		Total Length at Annulus (cm)				
			TL(cm)	Wt(kg)	1	2	3	4	5
1968	2	8	35.3	0.45	13.5 (13.5)	25.9 (12.4)			
1967	3	12	49.5	1.36	13.2 (13.2)	27.7 (14.5)	41.4 (13.7)		
1966	4	44	60.5	2.59	13.5 (13.5)	26.2 (12.7)	41.7 (15.5)	53.6 (11.9)	
1965	5	5	65.9	3.27	15.2 (15.2)	25.7 (10.5)	38.4 (12.7)	50.5 (12.1)	60.8 (10.3)
Mean Calculated Total Length (cm)					13.9	26.4	40.5	52.1	60.8
Mean Increment of Growth (cm)					13.9	12.5	14.0	12.0	10.3
Total Length from Sum of Increments (cm)					13.9	26.4	40.4	52.4	62.7
Mean Calculated Weight (kg)					0.05	0.18	0.72	1.68	2.54

reported for native lake trout in Lake Michigan. An obvious possible explanation is that the studies cited on native Lake Michigan lake trout were conducted before the dominance of the alewife as a forage species in Lake Michigan. Change in food availability through introduction of forage fish has been reported previously as a factor improving lake trout growth (12, 15). Another possible consideration is a difference in genetic growth potential of the reintroduced lake trout compared with the native stock. The role of hatchery selection and the exact genetic background of the stocked strain could be major factors involved. The possibility of sampling bias due to small sample size may also be a consideration. Studies of lake trout age and growth in Lake Michigan (18, 20) and Bear Lake, Utah (3, 14) tend to show small sample size results in an over estimate of growth (Table 2). It is unlikely, however, that the degree of difference noted for growth of the reintroduced fish compared to native fish could be due to sample size alone.

TABLE 2. Mean calculated total lengths of native Lake Michigan lake trout and lake trout from Bear Lake, Utah.

		Total Length at Annulus (cm)				
Location/Source	No.	1	2	3	4	5
Lake Michigan						
Van Oosten (18) -----	97	12.4	21.6	30.2	39.1	46.7
Van Oosten and Eschmeyer (20) -----	811	8.4	18.0	25.7	30.7	35.6
Cable (4) -----	1319	15.0	22.1	28.4	34.5	39.4
Bear Lake, Utah						
McConnell <i>et al.</i> (14) -----	44	22.1	34.3	43.4	50.0	55.4
Bulkley (3) -----	295	13.7	21.3	29.5	37.6	44.5

Scar Analysis

Sea lamprey wounds or scars were found on 25% of the 69 lake trout captured in 1970 and fresh wounds occurred on 6% of the fish. Anonymous (1) found 2% of the lake trout captured in Indiana waters in 1969 had wounds. All scars and wounds on lake trout captured in 1970 were restricted to fish 50 cm or greater in total length. Of the 55 fish in this size group, 33% had scars or wounds. Daly (6) found most sea lamprey scars or wounds occurred on lake trout over 50 cm in Wisconsin waters of Lake Michigan but he also reported some heavy scarring on smaller fish. No scars or wounds were found on any coho salmon or chinook salmon captured in 1970.

Lake Trout Food Habits

Only 39 (55%) of the 71 lake trout captured had food contents in stomachs (Table 3). Fish were found in 98% of the stomachs and composed essentially all of the volume. The alewife was the single most important food item, occurring in 85% of the stomachs and comprising 93% of the total volume. Invertebrates (chironomid larvae, *Mysis* sp., and *Pontoporeia affinis*) were only a minor component of the

diet for all sizes combined. In Cayuga Lake, New York, Galligan (10) found fish in 95% of lake trout stomachs and alewives were present in 80%. Wright (21) reported a frequency of 80% for fish in his study of immature lake trout from Lake Michigan. He noted alewives and sculpins were found in 28% and 33% of the stomachs respectively.

TABLE 3. Percent volume and percent frequency of occurrence (parenthesis) of food items in stomachs of lake trout, coho salmon, and chinook salmon collected in Indiana waters of Lake Michigan in 1970.

Item Consumed	Lake Trout	Coho Salmon	Chinook Salmon
Fish -----	100(98)	100(97)	100(100)
Alewife -----	93(85)	97(79)	100(76)
Slimy sculpin -----	1(5)		
Mottled sculpin -----	T ¹ (3)		
Rainbow smelt -----	6(5)	3(3)	
Unidentified -----	(13)	(24)	(28)
Invertebrates -----	T(13)	T(6)	T(3)
Insects -----	T(5)	T(6)	
Chironomidae -----	T(5)		
Miscellaneous ² -----		T(6)	
Crustaceans -----	T(8)		T(3)
Mysis sp. -----	T(5)		
Pontoporeia affinis -----	T(5)		T(3)
Stomachs Examined -----	39	34	29
Length Range in cm. -----	30-76	46-58	25-68

¹ T is trace, less than 0.5%.

² Composed of adult terrestrial Coleoptera, Diptera, and Hemiptera.

Fish size was a factor in determining the type food eaten by lake trout (Table 4). Alewives were the most important item consumed on a percent volume and frequency basis for lake trout in the following three length intervals: 30-37, 38-47, and 48-76 cm. Volumes ranged from 92 to 100% and frequency of occurrence ranged from 75-100%. Lake trout 58.3 cm or greater in length tended to consume large alewives (126-182 mm) while lake trout smaller than 58.3 cm tended to consume some small alewives (70-178 mm) (Table 5). Crustaceans, *Pontoporeia affinis* and *Mysis* sp., were found only in stomachs of lake trout less than 48 cm total length. They occurred in 25-50% of the stomachs and *Mysis* sp. comprised 8% of the volume while *Pontoporeia affinis* accounted for only a trace. Lake trout less than 38 cm total length have been found to feed more extensively on invertebrates, particularly crustaceans (*Mysis* sp. or *Pontoporeia affinis*), while lake trout greater than 38 cm have been found to feed exclusively on fish (7, 9, 13, 19, 21).

Coho Salmon and Chinook Salmon Food Habits

A greater percentage of stomachs of coho salmon and chinook salmon contained food compared to those of lake trout sampled. The stomachs of 34 of 47 total coho salmon captured mainly in May had

food contents while stomachs of 29 of the 48 chinook salmon captured primarily in October contained food items. Fish were the dominant items consumed by both species (Table 3). Alewives were found in 79% of coho salmon and 76% of chinook salmon stomachs and accounted for 97% and 100% respectively of the volumes. Rainbow smelt (*Osmerus mordax*) occurred in 3% of the coho salmon stomachs and made up 3%

TABLE 4. Percent volume and percent frequency of occurrence (parenthesis) of food items in stomachs of three length intervals of lake trout collected in Indiana waters of Lake Michigan in 1970.

Item Consumed	Length Interval (cm)		
	30-37	38-47	48-76
Fish -----	92 (75)	100 (100)	100 (100)
Alewife -----	92 (50)	65 (50)	98 (94)
Slimy sculpin -----		35 (50)	
Mottled sculpin -----			1 (3)
Rainbow smelt -----			1 (7)
Unidentified -----	(25)	(25)	(10)
Invertebrates -----	8 (50)	T (50)	T (10)
Insects -----		T (25)	T (10)
Chironomidae -----		T (25)	T (10)
Crustaceans -----	8 (50)	T (25)	
Mysis sp. -----	8 (50)		
Pontoporeia affinis -----	T ¹ (25)	T (25)	
Stomachs Examined -----	4	4	31

¹ T is trace, less than 0.5%.

TABLE 5. Total length of measurable alewives in stomachs of lake trout, coho salmon, and chinook salmon collected in Indiana waters of Lake Michigan in 1970.

Salmonid Total Length (cm)	Alewife Total Length (MM)					
	Lake Trout		Coho Salmon		Chinook Salmon	
	Range	Mean	Range	Mean	Range	Mean
25.4-27.2					88	88
27.8-30.2					65-80	73
30.3-32.8					67-92	82
32.9-35.3	133	133			84	84
35.4-37.8						
37.9-40.4						
40.5-42.9						
43.0-45.5	148	148				
45.6-48.0			63-67	65		
48.1-50.5	75-133	113	72-190	138		
50.6-53.1	107-175	146	152-186	166		
53.2-55.6	178	178	68-159	103		
55.7-58.2	70-176	123	67-170	93	91-93	92
58.3-60.7	139-179	155				
60.8-63.2	143-182	161				
63.3-65.8	126-155	143				
65.9-68.3	151-177	169			118-132	123
68.4-70.9						
71.0-73.4	152	152				

of the volume but they were not found in chinook salmon stomachs. Coho salmon consumed alewives between 63 to 190 mm while chinook salmon fed on alewives from 65 to 132 mm long (Table 5). The difference in maximum size of alewives consumed is probably related to season since, as noted, most chinook salmon were captured in October when large alewives are not present due to migration to deeper offshore water. Anonymous (1) reported an occurrence of 64% for alewives and 7% for smelt in stomachs of coho salmon from Indiana waters in 1969.

Summary

- 1) The mean calculated total lengths of known-age reintroduced lake trout for first through fifth years of age revealed faster growth than reported for original native Lake Michigan lake trout. Stocked fish were also slightly heavier at a given length. Factors which may be implicated in the rapid growth of the reintroduced lake trout include genetic differences, the readily available alewife forage base, and the possibility of bias due to the low sample size. The growth differences noted, however, appear too great to be attributed solely to the latter factor. Future studies may provide additional insight to growth characteristics of the reintroduced lake trout.
- 2) Sea lamprey scars or wounds were found on 25% of the lake trout captured and were restricted to fish 50 cm or greater in total length. No scars or wounds were noted on coho salmon or chinook salmon.
- 3) The alewife was the major food consumed by lake trout (93 percent volume), coho salmon (97 percent volume) and chinook salmon (100 percent volume). Lake trout smaller than 58.3 cm total length tended to consume some smaller alewives (70-187 mm) while larger lake trout ate larger alewives (126-182 mm) exclusively.

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Four Economic Models of Fisheries Management Programs for Ponds or Small Lakes

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On the Hoosier National Forest in the late 1950's and early 1960's, wildlife waterholes (generally too small or shallow for efficient fish production) began to be supplemented by small fishing ponds of 1 to 3 acres. After initial stocking, these waters generally received little fish management attention. Often the State fisheries agency was too restricted by lack of time, funds, and personnel to devote much management attention to these mini-waters. The Forest Service lacked personnel to do this work, and also had doubts that its responsibilities extended to manipulation and management of this pond fishery resource. These ponds were constructed, stocked, and orphaned (i.e., largely ignored), except that Forest wildlife biologists noted the beaten paths around the shores.

This angler-use, despite the absence or insufficiency of management, has led Forest Service wildlife and fisheries personnel to wonder how much recreational use these small ponds (under 5 acres) could provide if properly managed. In addition, are there recreational benefits sufficient to make them economically feasible? The economic measurement of these small waters is more difficult than the environmental, because small ponds have seldom been evaluated on a benefit/cost scale. Even rarer, or non-existent, is an economic evaluation of a complete program consisting of a large series of ponds. Even when ponds or small lakes have been evaluated economically, they have been judged on the before-and-after change in fishing use (a quantitative factor) rather than any change in fishing quality, or better still, a combination of both quantitative and qualitative changes.

In measuring recreational benefits of lakes or ponds, fisheries managers have usually assigned a mean figure as the value of a "fishing day." If, for instance, the assigned value of a fishing day (or trip) is \$7.00, this figure is applied equally to waters of low fishing quality as well as to waters of highly productive fishing. It would seem obvious that more productive waters have a higher intrinsic value to the fisherman.

These economic models developed in this study are based upon four arbitrary fishing quality categories (poor, medium, good, and excellent) with different trip values assigned to each. By basing the value of a fishing trip on the potential quality of the experience, the fisheries manager can measure economically the impact of his management practices, and determine their cost effectiveness.

Th subsequent pond program models are based upon a series of 50 ponds (roughly equating to the Hoosier National Forest situation). For convenience, the average size used is one acre, which may be slightly lower than the actual forest average. An explanation of various components of these models (many having arbitrary judgment factors)

may best be done by taking each of the basic elements (horizontal elements A-D and vertical elements I-VIII) in order.

Horizontal Elements of Models (A-D)

Qualitative: Gives a value preference to waters of good fishing quality over those waters of poorer fishing quality. (No fishing: 0%; poor fishing quality: 25%; medium: 50%; good: 75%; and excellent: 100%).

Vertical Elements of Models (I-VIII)

Element 1: This is merely an arbitrary assignment of categories for a 50-pond program which had largely been in place for eight years or more years with no management. The assignment of ponds to quality categories is based on my forecast of what I would expect to find were I to survey these 50 ponds at present (Table 1).

Element II: The fishing use component (U) is measured in visitor-days (i.e., the aggregate of 12 hours of fishing, whether by one individual fishing 12 hours or 12 individuals fishing one hour each). I have used an average fishing use of .125 V-D per day per pond, which represents 1½ fisherman-hours/pond/day.

D = Days in fishing season (without ice fishing considered).

V = Value: The value assigned to a day of fishing; in these models the value used is \$21/day for a 12-hour fishing day.

G = Value Gradient: The quality index (a percentage of potentially attainable fishing quality). The percentage gradient for the particular category $\times$ the value of a visitor-day of excellent fishing (\$21) gives the fishing day value for other categories (e.g., good: $\$21 \times 75\% = \$15.75$; medium: $\$21 \times 50\% = \$10.50$; poor: $\$21 \times 25\% = \$5.25$).

P = Number of ponds in the particular category. In these models: 0 in excellent; 5 in good; 10 in medium; and 35 in poor.

Element III: Surveys (S). This is the cost of determining the present status of ponds by fisheries surveys. This is based on one crew-day per pond.

Biologist	\$ 60.00
Assistant	30.00
Operation and Maintenance	40.00
	\$130.00/survey

Element IVa: Renovation (R). This is the cost of chemical renovation of ponds. It is estimated that a two-man crew could do 2 ponds per day. Further, it is assumed that renovation would be needed every eight years. Total costs for a renovation process are prorated over the eight-year cycle to get an annual cost figure.

Biologist	\$30.00
Assistant	15.00
Chemicals	25.00
Operation and Maintenance	10.00
	\$80.00/Renovation

TABLE 1. "Core" data—vertical elements I-IV.

Economic Model I For Small Pond Program	(A) Ponds of Excellent Fishing Quality (Value Gradient : 100%)	(B) Ponds of Good Fishing Quality (Value Gradient : 75%)	(C) Ponds of Medium Fishing Quality (Value Gradient : 50%)	(D) Ponds of Poor Fishing Quality (Value Gradient : 25%)	(T) Annual Totals For 50-Pond Management Program
I Estimated present acres of:	0	5	10	35	50
II Present fishing benefits per year (B _A , B _B , B _C , B _D , B _T @ \$21/visitor-day for excellent quality fishing:	(1) .125 V-D•200•\$21 = \$525 (2) \$525•100%•0 = \$0	(1) .125 V-D•200•\$21 = \$525 (2) \$525•75%•5 = \$1968.75	\$2625.00	\$4593.75	\$9187.50
III Cost of deter- mining present status (i.e., fisheries sur- veys) @ \$130/pond:	a. Annual surveys: \$0/yr b. Biennial surveys: \$0/yr c. Triennial surveys: \$0/yr	\$650/yr \$325/yr \$217/yr	\$1300/yr \$650/yr \$433/yr	\$4550/yr \$2275/yr \$1517/yr	\$6500/yr \$3250/yr \$2167/yr
IV a. Cost of renovation @ \$80/acre/or. \$10/acre/yr. b. Cost of restocking @ \$40/acre or \$5/acre/yr. c. Cost of other management @ \$20/acre/yr.	\$0/yr \$0/yr \$0/yr	\$50/yr \$25/yr \$100/yr	\$100/yr \$50/yr \$200/yr	\$350/yr \$175/yr \$700/yr	\$500/yr \$250/yr \$1000/yr

Element IVb: Restocking (R_s). The cost of the restocking project is, like renovation, based upon an eight-year cycle, and costs prorated over the period to calculate annual costs.

Element IVc: Other management (O_m). This component includes costs of other management practices such as aquatic weed control, creel censuses, structure examination and maintenance, access maintenance, etc. These are combined into a single, arbitrary estimate of \$160 for the eight-year period (\$20/pond/year).

Element V: Total Management Costs. The foregoing elements (I-IV and A-D) make up the data base or "core" of the models (Table 1). This element and those that follow (V-VIII) I have termed "subcore" data (Table 2). Element V is the summation of III and IV and merely makes their combined values more evident and visible.

Element VI: Benefits-Foregone (B'). Benefits-Foregone is a means of measuring benefits *that would have accrued* had we done something differently (e.g., if we had provided 6 lakeshore picnic tables; had we installed a mile-long nature trail; or if we had provided management which maintained ponds at excellent fishing quality). If by installing a certain facility or practice, we could attract a certain number of additional users, at a certain cost per user, then this amount (over and above what we presently have) is benefits-foregone—we forego them by lack of a picnic table, a trail, or a pond management program. In these models I have supposed that intensive fisheries management of small ponds could raise a pond's fishing quality no more than one category except that ponds having no fishing or having "poor" quality fishing could be raised 2 classes to "good." This is the postulate upon which B' computations are based. I have assumed that with a pond management program in operation, the "poor" and "medium" ponds would be improved to "good" quality and the "good" ponds to "excellent." It is a simple matter then to derive the annual lost benefits (B'_A , B'_B , B'_C , B'_D , B'_T). From benefits accruing under management, one merely subtracts present benefits in the absence of management.

Element VII: This (like Element V) is simply an addition of two elements from the model (II and VI). Again, the intent is merely to make the total recreational benefits more visible in the model.

Element VIII: The benefit-cost ratio has become so prevalent in the past twenty years that I doubt that it needs any explanation. The projected benefits of a proposed project are divided by the costs of that proposal and it is presumed that a project having a ratio greater than 1.0 is economically feasible. Herein, I have not included Element II benefits, since they are actually benefits accruing under a system of no management, thus are not legitimately attributable to the pond management program being measured in the model. Only the benefits-foregone (i.e., the calculated additional benefits that would accrue were the management program installed) are weighed against the costs of that management program.

These elements are the data required to build an economic model of most recreational activities, not merely for fishing.

TABLE 2. "Sub-core" data—vertical elements IV-VIII.

Economic Model I For Small Pond Program	(A) Ponds of Excellent Fishing Quality (Value Gradient : 100%)	(B) Ponds of Good Fishing Quality (Value Gradient : 75%)	(C) Ponds of Medium Fishing Quality (Value Gradient : 50%)	(D) Ponds of Poor Fishing Quality (Value Gradient : 25%)	(T) Annual Totals For 50-Pond Management Program
V Survey and management costs (III & IV) with:					
a. Annual surveys.	\$0/yr	\$825/yr	\$1650/yr		\$8250/yr
b. Biennial surveys	\$0/yr	\$500/yr	\$1000/yr		\$5000/yr
c. Triennial surveys:	\$0/yr	\$392/yr	\$783/yr		\$3917/yr
VI Benefits-fore- gone: (i.e., potential rec- reation bene- fits that <i>could</i> be gained by instituting a management program that would improve	\$0/yr	\$656.25/b-f/yr "Excellent" fishing value/pond/yr (\$525• 100% = \$525) — present fishing value/pond/yr (\$525•75% — \$393.75) = \$131.25•No. of ponds in category (5) = \$656.25	\$1312.50/b-f/yr	\$9187.50/b-f/yr	\$11,156/b-f/yr

"poor" and
"medium,"
quality fishing
to the "good"
category, and
"good" to
"excellent."
(B', B', B',
B', B', B')

VII Accrued recreational benefits with pond management program (II+VI) :		\$0/yr	\$2625/yr	\$3937.50/yr	\$13,781.25/yr	\$20,343/yr
VIII Benefit-cost ratios with:						
a. Annual surveys and management	$\frac{\text{annual benefits-foregone}}{\text{annual surveys} + \text{annual mgt.}}$	=	Undiscounted \$11,156 \$ 8,250	=	Discounted (10%) \$10,142 \$ 7,500	= 1.35 b/c ratio
b. Biennial surveys and annual management:	$\frac{\text{annual benefit-foregone}}{\text{biennial surveys} + \text{annual mgt.}}$	=	\$11,156 \$ 5,000	=	\$10,142 \$ 4,546	= 2.23 b/c ratio
c. Triennial surveys and annual management:	$\frac{\text{annual benefit-foregone}}{\text{triennial surveys} + \text{annual mgt.}}$	=	\$11,156 \$ 3,917	=	\$10,142 \$ 3,609	= 2.85 b/c ratio

MODEL I

In Model I, certain assumptions are made which permit the construction of a model around these assumptions. First, I assumed that the program included 50 ponds or small lakes. Second, these bodies of water had received no management for the past 10 years. Third, these ponds or small lakes had segregated into several quality classes in the following manner: 5 were still in the "good fishing" category; 10 were "medium fishing;" and 35 had degraded to "poor fishing." None were still "excellent" in fishing quality. Fourth, renovation (R) and restocking (R_s) could be performed one year and the waters (all 50 ponds or lakes) would be "good fishing" the following year (Program Year I). Fifth, all waters would consistently retain their good fishing rating throughout the period considered by the model. Sixth, program costs and benefits have not been discounted as generally required in most governmental economic analyses. Seventh, there are some serious doubts that the use-level of 300 hrs./acre/year and the quality categories that we have projected are concurrently sustainable.

At the time of formulation it was recognized that some of these assumptions were either invalid or questionable. However, Model I is merely a primary model to serve as a base for modification and sophistication of later, more realistic models. Model I (Fig. 1) was built with these assumptions, and Table 3 indicates the benefit-cost array for this model. It would have a favorable b/c ratio, but, as previously noted, it has a number of inherent weaknesses that make it unrealistic for field use.

The most flagrant weakness involves assumption No. 4. There is a time lag in the "start-up" of a program which is not considered in Model I. It takes time to survey a body of water; determine from the survey data that reclamation is indicated; do the reclamation work; then restock. The most critical time lag, however, is the period required for fish to grow from the fingerling stage (usually stocked) to a size desirable to the sport fisherman. This is generally about 3 years in a reclaimed lake or pond.

Let's construct another model (Model II) which corrects this "instantaneous conception" an error, and includes instead a "start-up" or Pre-model Stage. In addition, I have extended the program period to a 16-year cycle to compare to a later 16-year cycle model. Another weakness, in the view of economists, is that Model I benefits and costs have not been discounted. Discounting can have a significant effect on the cost effectiveness of a program (i.e., the b/c ratio).

Model II (Fig. 2) is a more logical program than Model I, and also produces a favorable b/c ratio (Table 3). In Model II, the instantaneous start-up defect has been corrected by preceding the active model years with a pre-model, developmental stage. In addition, all benefits and costs have been discounted. One can see (Table 3) that in this more realistic model the costs in the developmental (Pre-model) stage exceed the benefits for this period. Additionally, when discounted, these high early costs in the forward part of the program life significantly affect the b/c ratio.

FIGURE 1. An 8-year program model with instantaneous "start-up" and constant quality segments.

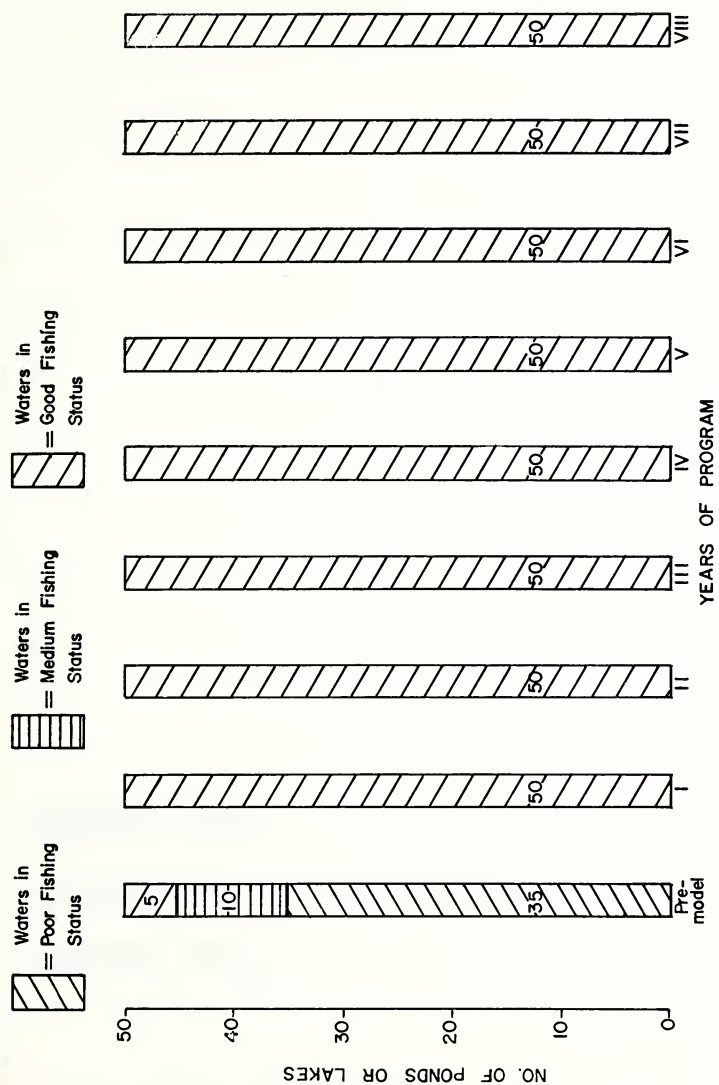


FIGURE 1.

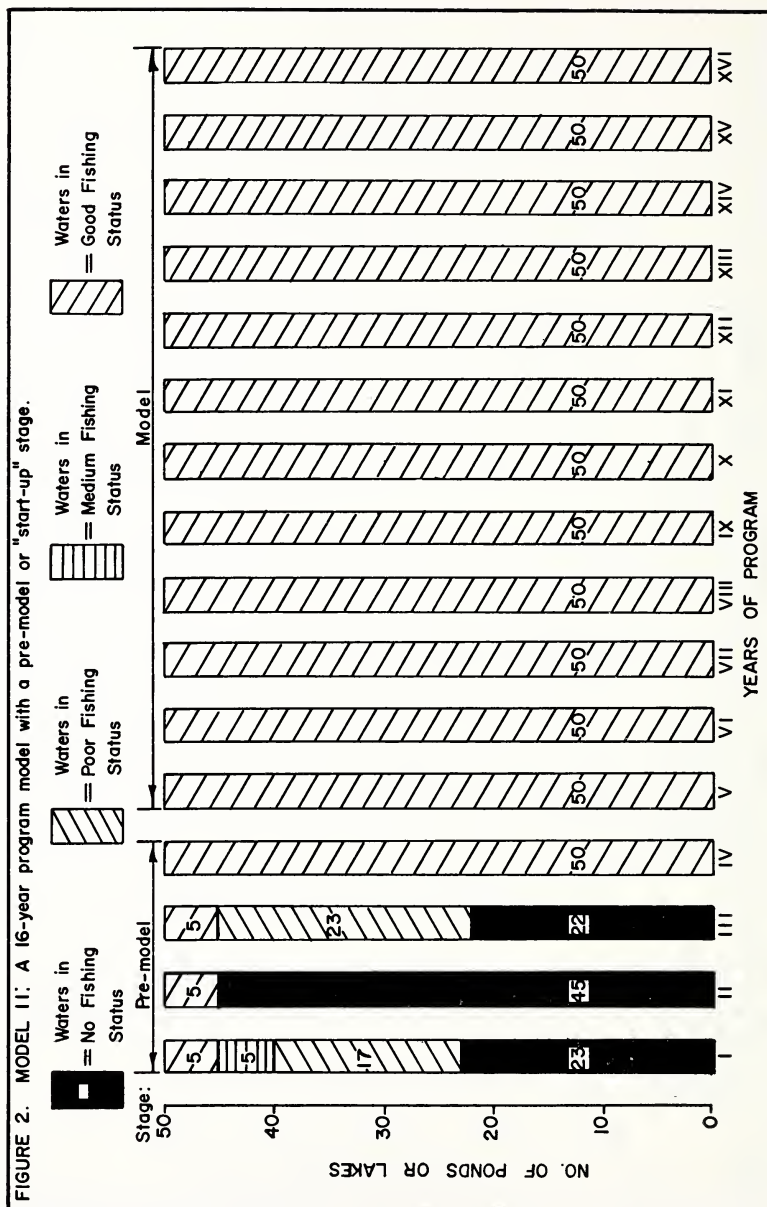


FIGURE 2.

TABLE 3. *Discounted Costs and Benefits for Model II (using Biennial Surveys Only.)*

Year		6%	10%	15%	20%
COSTS					
Pre-model	1 -----	\$ 5,708 ¹	\$ 5,500	\$ 5,261	\$ 5,041
	2 -----	5,331	4,950	4,529	4,159
	3 -----	3,568	3,193	2,794	2,459
	4 -----	3,366	2,903	2,430	2,050
Model Stage	5 -----	3,737	3,105	2,486	2,010
	6 -----	3,525	2,823	2,162	1,675
	7 -----	3,325	2,566	1,880	1,396
	8 -----	3,137	2,333	1,635	1,163
	9 -----	2,960	2,121	1,422	969
	10 -----	2,792	1,928	1,236	808
	11 -----	2,634	1,753	1,075	673
	12 -----	2,485	1,593	935	561
	13 -----	2,344	1,449	813	467
	14 -----	2,212	1,317	707	390
	15 -----	2,087	1,197	615	325
	16 -----	1,969	1,088	535	271
		\$51,180	\$39,819	\$30,515	\$24,417
BENEFITS					
Pre-model	1 -----	\$ 4,210	\$ 4,057	\$ 3,881	\$ 3,719
	2 -----	4,205	3,094	3,573	3,281
	3 -----	0	0	0	0
	4 -----	4,470	3,855	3,227	2,722
Model Stage	5 -----	8,337	6,927	5,547	4,484
	6 -----	7,865	6,298	4,823	3,736
	7 -----	7,420	5,725	4,194	3,114
	8 -----	6,999	5,204	3,647	2,595
	9 -----	6,603	4,731	3,172	2,162
	10 -----	6,230	4,301	2,758	1,802
	11 -----	5,877	3,910	2,397	1,502
	12 -----	5,545	3,554	2,085	1,252
	13 -----	5,230	3,232	1,813	1,043
	14 -----	4,934	2,937	1,576	869
	15 -----	4,656	2,671	1,371	724
	16 -----	4,392	2,428	1,117	604
		\$86,973	\$63,734	\$45,181	\$33,609

¹All dollar values rounded to the nearest dollar.

b/c Ratio: 1.70 1.60 1.48 1.38

There are, however, assumptions in this latest model that still trouble me. After the Pre-model development stage, there is an implicit assumption that the management program would keep fishing quality at a high level indefinitely (to the *i*th year). Even after we chopped the program to a 16-year management cycle with subsequent replications, there is an assumption that from Years V-XVI there is no decline in fishing quality. I am not at all confident that the level of management funded in this model can maintain this quality (i.e.,

without highly intensive management such as increasingly intensive weed control; remedial stocking of game species; removal of infesting species by trapping, netting, or electro-fishing; etc.).

An Improved Version of the 16-year Model (Model III)

I am going to explore another 16-year model which includes what appears to me to be a more normalized relationship between fishing quality and program age. Let's assume that management funded as indicated in the model *cannot* indefinitely hold fishing quality in the Good (or Excellent) category. In spite of this level of management, fishing quality will fall in later years of the program. Let's hypothesize that during the 16-year management cycle, these waters pass through four stages:

- (1) Developmental (Pre-model): Years I-IV
- (2) "Good" (Peak): Years V-X
- (3) "Medium" (Early Decline): Years XI-XIV
- (4) "Poor" (Pre-renovation): Years XV and XVI

This may be an overly-severe affront to our management capabilities, but let's run the model for this situation, anyway. It may be instructive and give us ideas on how to improve future models. Table 4 shows that in Model III the temporal decline in quality has a significant effect on the b/c ratio, lowering it from 1.70 to 1.27 at the 6% discounting rate. The ratio figure is, however, still on the profitable side.

By running Model III another probable modification becomes obvious. In terms of present worth, by Year XV all fishing benefits are valueless. Conversely, costs of \$1149-\$4055 are still accruing (dependent upon the interest rate used). Model III tells us plainly that this should be a 14-year program rather than a 16-year one. By chopping the management cycle to 14-years we avoid 2 years of losses totaling \$1100 to \$4000. Model III (Fig. 3), based upon biennial surveys, corrects most of the defects of previous models and retains a favorable cost effectiveness. However, it has a potential weakness concerned with the seventh assumption upon which these models have been based. It calculates benefits on a high use-level of 300 hrs./acre/year. I have some doubts that we can sustain the quality of fishing that we have projected in these models at a fishing pressure of 300 hrs./acre/year.

Model IV-A: An Automatic Octennial Management Program

In addition to lowering the use-level to 200 hrs./acre/year, there is one more frequency interval for surveys that we should consider. It has its genesis in the high percentage of management costs that are tied up in inventorying these waters (surveys). We found annual surveys to be very expensive (nearly 80% of all management costs) and we had some doubts about the biological sufficiency of surveying these waters every third year (triennial surveys). We used biennial survey costs as a compromise in Models II and III. However, even

TABLE 4. *Discounted Costs and Benefits for Model III (using Biennial Surveys Only).*

Year		6%	10%	15%	20%
COSTS					
Stage 1	1	\$ 5,708 ¹	\$ 5,500	\$ 5,261	\$ 5,041
	2	5,331	4,950	4,529	4,159
	3	3,568	3,193	2,794	2,459
	4	3,366	2,903	2,430	2,050
Stage 2	5	3,737	3,105	2,486	2,010
	6	3,525	2,823	2,162	1,675
	7	3,325	2,566	1,880	1,396
	8	3,137	2,333	2,635	1,163
	9	2,960	2,121	1,422	969
	10	2,792	1,928	1,236	808
Stage 3	11	2,634	1,753	1,075	673
	12	2,485	1,593	935	561
	13	2,344	1,449	813	467
	14	2,212	1,317	707	390
Stage 4	15	2,087	1,197	615	325
	16	1,969	1,088	535	271
		\$51,180	\$39,819	\$30,515	\$24,417
BENEFITS					
Stage 1	1	\$ 4,210	\$ 4,057	\$ 3,881	\$ 3,719
	2	4,205	3,904	3,573	3,281
	3	0	0	0	0
	4	4,470	3,855	3,227	2,722
Stage 2	5	8,337	6,927	5,547	4,484
	6	7,865	6,298	4,823	3,736
	7	7,420	5,725	4,194	3,114
	8	6,999	5,204	3,647	2,595
	9	6,603	4,731	3,172	2,162
	10	6,230	4,301	2,758	1,802
Stage 3	11	2,420	1,620	987	618
	12	2,283	1,464	859	515
	13	2,154	1,331	746	430
	14	2,032	1,210	649	358
Stage 4	15	0	0	0	0
	16	0	0	0	0
		\$65,228	\$46,316	\$38,063	\$29,536

¹All dollar values rounded to the nearest dollar.

b/c Ratio 1.27 1.27 1.25 1.21

biennial inventories consume 65% of total management costs. We need to explore a management system that eliminates surveys entirely.

Model IV-A is based upon a management system that eliminates fisheries surveys, and routinely reclaims the ponds or lakes on a set time schedule of 8 years. Bass-bluegill populations of the average pond or lake go through temporal changes in sport fishing quality. I have

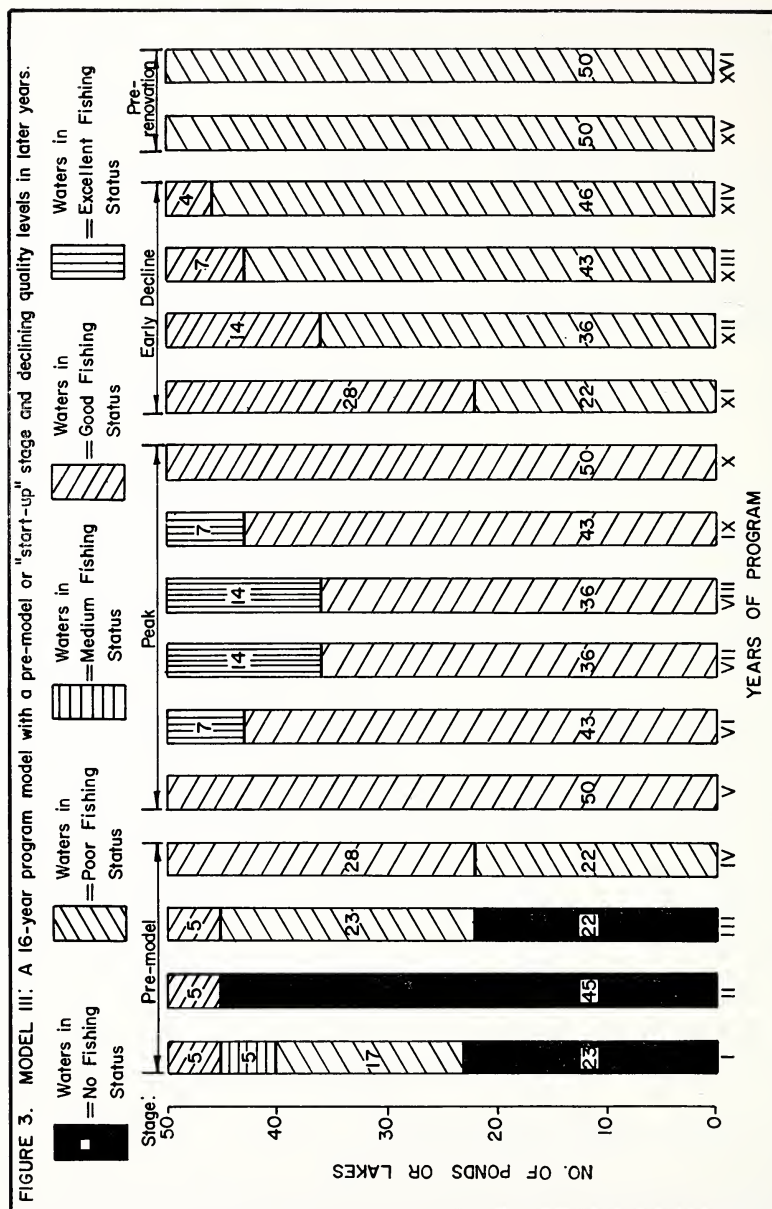


FIGURE 3.

theorized that a pond (stocked in Year 0 with fingerling bass and bluegills) goes through an unmanaged cycle approximated by the following schedule:

Year I:	No fishing
Year II:	Poor quality
Year III:	Medium quality
Year IV:	Good or excellent quality
Year V:	Good or excellent quality
Year VI:	Good quality
Year VII:	Medium quality
Year VIII:	Poor quality

I suspect that the unmanaged cycle presented above is somewhere near the average. Some ponds will have only a year or two of quality production; conversely, some may go 10 or 12 years before declining. (The user may want to modify the arrangement of quality levels to suit his own ideas on the rise and decline of pond populations.) When one runs Model IV-A (Fig. 4) at a realistic discount rate of 10%, it shows a profitability of more than \$20,000 over the 8-year cycle (Table 5).

TABLE 5. *Model IV-A: 1st Cycle Totals*

Year	Discounted Costs (10%)	Discounted Benefits (10%)	Difference
I -----	\$ 2,418	\$ 4,932	+\$ 2,514
II -----	2,855	3,543	+ 1,688
III -----	1,687	3,418	+ 1,731
IV -----	1,533	3,944	+ 2,411
V -----	1,394	4,238	+ 2,844
VI -----	1,267	4,445	+ 3,178
VII -----	1,252	4,221	+ 3,069
VIII -----	1,047	3,755	+ 2,708
	<u>\$12,353</u>	<u>\$32,496</u>	<u>\$20,143</u>
	b/c ratio = $\frac{32,496}{12,353} = 2.63$		

The cost effectiveness of Model IV-A looks impressive upon cursory examination. Table 5 does not, however, give adequate consideration to impacts of the program—both costs and benefits. Table 5 merely shows the benefit-cost efficiency of a single cycle program put into operation with the assumed composition of quality class ponds. What, for instance, is the cost differential between the Model IV-A program and the present non-management situation? The latter, if continued through another 8-year period in place of the Model IV-A program, would produce \$23,340 of present worth benefits, without (theoretically) any costs. Should not the benefits from a system of non-management be subtracted from the benefits of a management program to derive the differences between them?

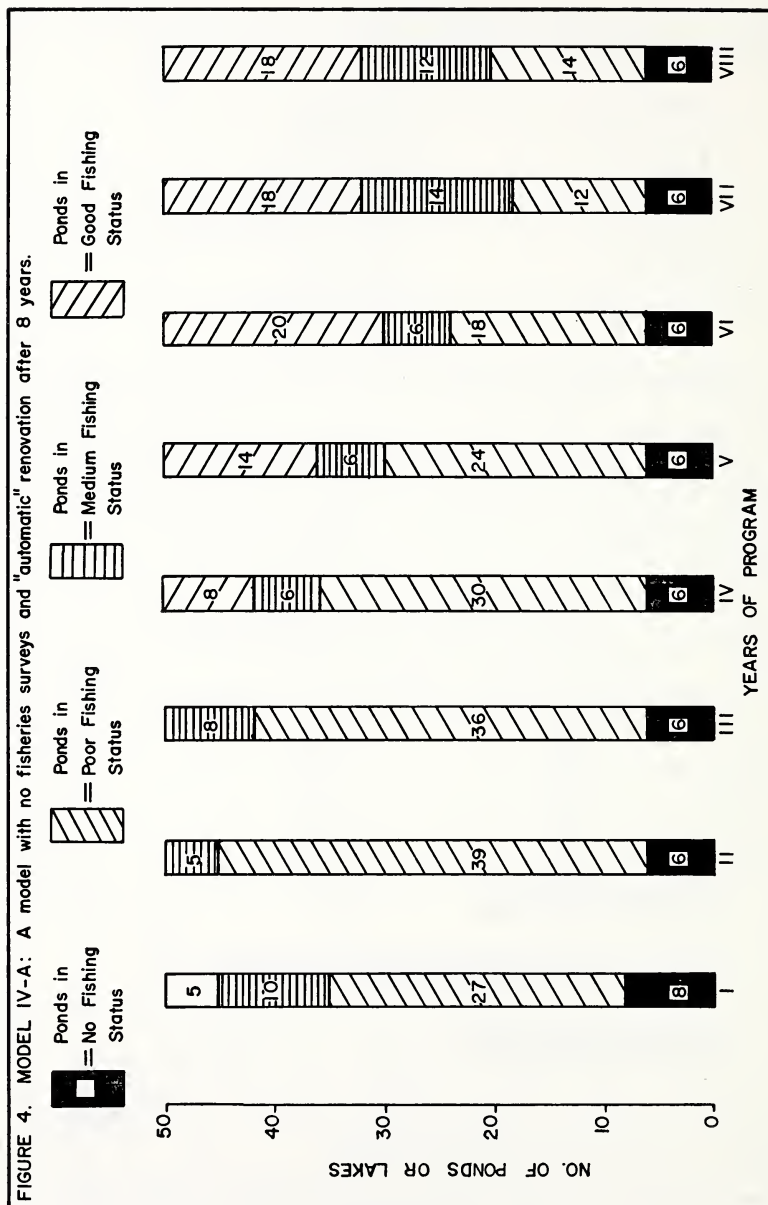


FIGURE 4.

In weighing the two systems in this manner, the Model IV-A system shows benefits of \$32,496 minus \$12,353 in costs, or a profit of \$20,143. The nonmanagement system gives \$25,293 in benefits, minus no costs, or a profit of \$25,293. On the basis of these figures alone, it would appear more profitable to forego management. Let's look more closely at the management model, however. Notice (Fig. 5) that in the non-management cycle, ponds are in the descending leg of their quality curve, and that from Year III on, we will be faced with 50 consistently poor ponds. The 10 medium ponds and 5 good ponds will in one or two years be poor fishing. Practically all the benefits assigned to these ponds come from consistently poor fishing. Further, the volume of these benefits (despite the low value: \$87.50 V-D/acre/yr) comes from the assumption of a high intensity of fishing activity (i.e., a fishing intensity of 200 hrs./acre/yr.). It is not realistic to expect fishing pressure to remain near capacity when quality has fallen to low levels.

Conversely, at the end of the 8-year management cycle many of the Model IV ponds are still at their peak or even on the ascending leg of their quality curve. This fact insinuates that we should follow them through a longer period. Let's compare the non-management and Model IV management systems through another 8-year period *without* any further renovation-restocking operations in the Model IV version (i.e., we will let Model IV ponds settle back to "poor" by their own gravity, and we will term this modification Model IV-B).

Model IV-B, then, is merely Model IV-A hooked to a subsequent 8-year cycle with no costs except Other Management. It is Year XV before all ponds settled into the "poor" category (Fig. 6). The Model IV-B renovation-restocking operations of the first cycle (Years I-VIII) carry higher recreational benefits (i.e., "good" and "medium" quality levels) through Years IX to XIV. This is, of course, because it takes six years for a group of ponds to go from "poor" to higher categories and back to "poor" again. The precipitation or "fall-out" of these groups extends the effects considerably beyond the termination of the R-R_s operations—a time-lag or "coasting" situation.

This modification (Model IV-B) is attractive economically since it eliminates R-R_s costs in the second cycle while retaining higher quality benefits induced by first cycle operations. This is basically a 16-year program with all R-R_s operations in the first half; only O (Other management) costs are incurred in the second half of the program. One should consider, however, that these management programs parallel physical laws of inertia. It takes considerable "energy" (time and funds) to overcome the inertia of a resting stage (poor quality) and get the program functioning. We need to examine whether or not it requires more energy to maintain a relative velocity in a program than to coast to "poor" fishing, then have to overcome the inertia of low production, and start up again. This can be tested by hooking two Model IV-A cycles together. (Although this was really what was anticipated for Model IV-A, for the sake of clarification let's call this 16-year model Model IV-C).

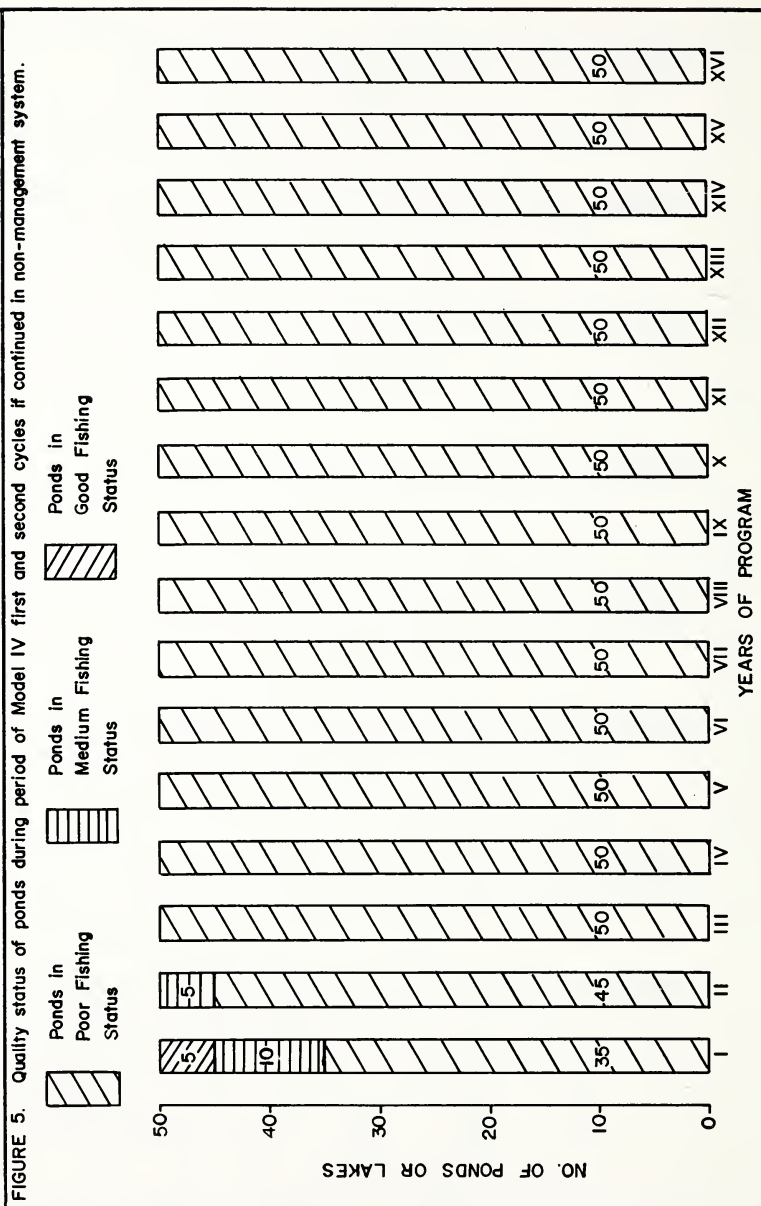


FIGURE 5.

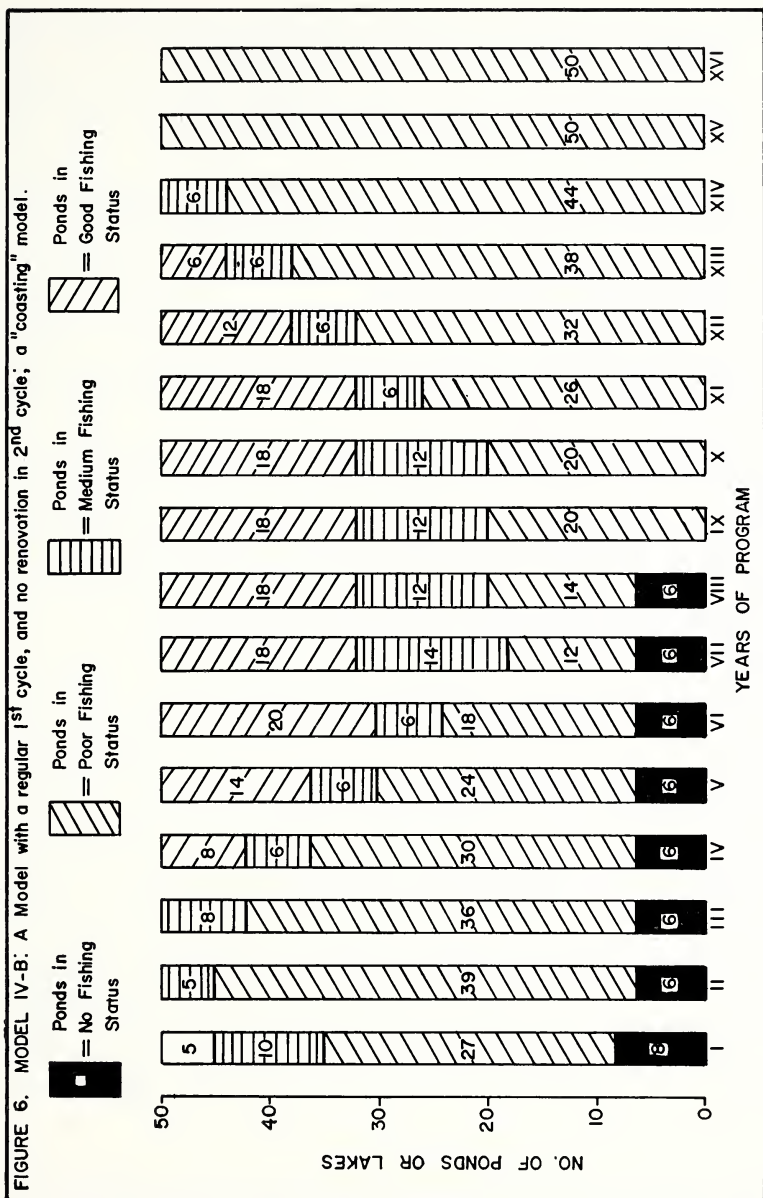


FIGURE 6.

We mentioned that it requires considerable management energy (i.e., time and funding) to move a program from a resting stage (low productivity) to a desirable level of recreation output. In these situations a constant flow of recreation products (herein, good fishing) may be preferable even though a more cyclic program might show some small financial advantages.

Comparing Model IV-B (Fig. 6) and Model IV-C (Fig. 7) on the basis of flow constancy, we can see that Model IV-C is much more consistent. After the start-up period of the first six years, 60%-64% of the ponds are producing acceptable fishing (medium, good); 24%-28% have degraded to poor fishing; and 12%-16% are out of production. If a second 16-year cycle is hooked to Model IV-C, the flow of Years XVII-XXXII would be similar to Years VII-XVI (i.e., a relatively constant flow). For most fisheries managers, the continuity of the IV-C program makes it preferable to Model IV-B, even if the latter had minor economic advantages.

The formula (Fig. 8) for the formulation of these models is a relatively simple one. In addition, it is one which can be used to measure many recreation activities, not fishing alone. In discussions of these models, I have been asked several questions concerning their use. Could you model larger lakes by the same technique? One can if he can provide the basic core data to the formula. On large lakes with multiple access points, accurate use data (U) may be the most difficult component to provide.

Can the arbitrary categories, or value gradients (G), that I have used be made more definitive? Although I have not defined the basis for my categorization in this paper, it has basically been as follows: "Excellent" fishing: a catch rate >1.1 fish/hour/angler; "good": 0.9-1.1 fish/hour/angler; "medium": 0.75-0.9; and "poor": <0.75 . If one has good harvest data he can use my scale, or revise it to harvest rates that he equates with excellent, good, medium, and poor fishing. Can other forms of recreation be modeled by using this formula? I think that most can. I could model grouse hunting, picnicking, or wildlife photography of rare animals with this formula, if the core data were available or could be realistically estimated.

The formula could be strengthened in special cases by inserting coefficients to more accurately describe factors such as aesthetic values, difficulty of access, or user attitude. There is much room for improvement of the modeling system, and the formulations explored in this paper are merely a start toward more sophisticated and accurate models.

FIGURE 7. MODEL IV.C: A Model with renovation in both 1st and 2nd cycles; two connected Model IV-A's following no management.

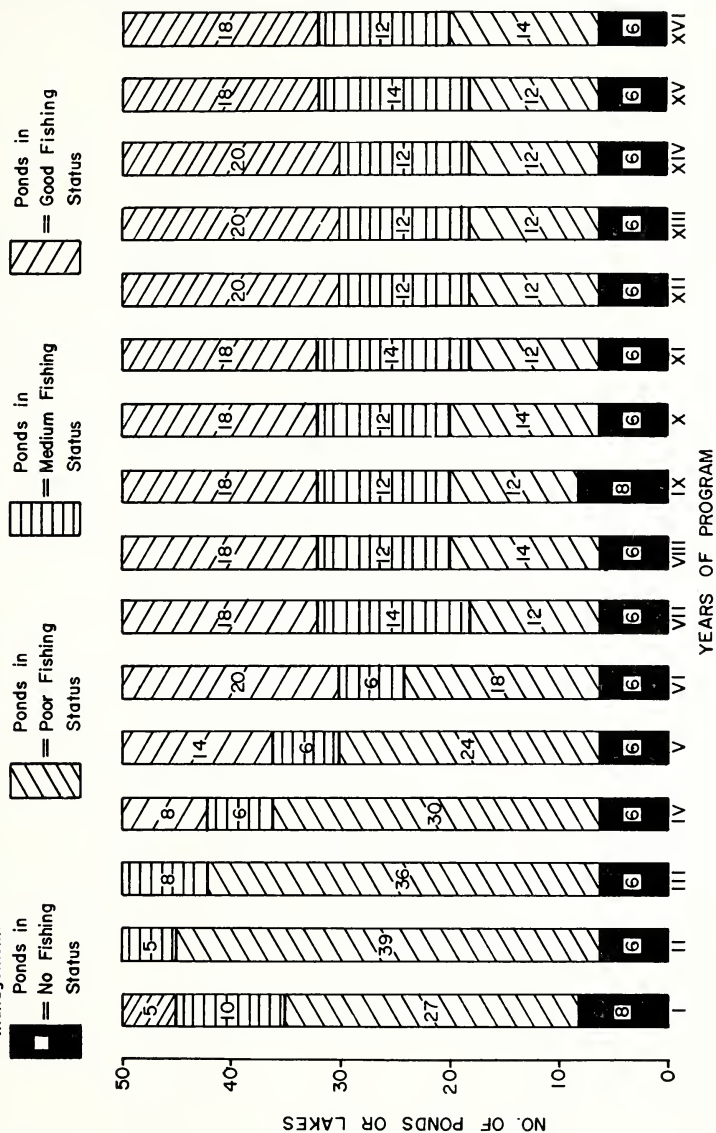


FIGURE 7.

FIGURE 8. Formula For Pond or Lake Management Program

$$(1) \quad \frac{\sum_{i=1}^n (P_B \cdot [U \cdot D \cdot V \cdot G \cdot B]_B) + \sum_{i=1}^n (P_C \cdot [U \cdot D \cdot V \cdot G \cdot B]_C) + \sum_{i=1}^n (P_0 \cdot [U \cdot D \cdot V \cdot G \cdot B]_0) \cdot \sum_{i=1}^n (1-\lambda)^i}{\sum_{i=1}^n (S+R+R_S+O) \cdot P_T \cdot \sum_{i=1}^n (1-\lambda)^i} = \frac{Dc B'_T}{Dc C_T}$$

which reduces to :

$$(2) \quad \frac{\sum_{i=1}^n (P_B \cdot B'_B) + \sum_{i=1}^n (P_C \cdot B'_C) + \sum_{i=1}^n (P_0 \cdot B'_0) \cdot \sum_{i=1}^n (1-\lambda)^i}{\sum_{i=1}^n (S+R+R_S+O) \cdot P_T \cdot \sum_{i=1}^n (1-\lambda)^i} = \frac{Dc B'_T}{Dc C_T}$$

FIGURE 8.

Fish community changes at one Vigo County, Indiana locality over a twelve year period

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Abstract

Seining was conducted over 12 years (28 collections) in a physically and ecologically stable site, at Otter Creek Dam, in Vigo County, Indiana, 5 mi. N. Terre Haute. A total of 52 species of fish was taken, or 52.8% of the species known to occur in Vigo County. Of these, 21 were considered as accidentals (occurred in less than 3 collections and/or represented by no more than 5 individuals). A total of 21,029 fish was taken in the 28 collections. There were 18 major species (those taken in at least 18 collections, with a total of over 100 individuals being collected). Only one species, *Etheostoma blennioides*, occurred in all 28 collections. *Pimephales notatus* and *Etheostoma caeruleum* occurred in 27, while three additional species occurred in 26.

There were pronounced differences in the total numbers of fishes per collection, and in numbers of fishes per species per collection, even though the area was ecologically quite stable. This variation appeared to be primarily seasonal in some species, due to long-term population changes in some, and was erratic in still others. These latter variations were thought to be due to sampling error, to schooling of fish, or to migration or erratic population changes.

Introduction

In recent years there has been much emphasis on ecology and conservation. Organismal data are being collected for purposes of writing environmental impact statements to determine environmental changes that may occur as a result of building a dam or factory, adding hot water or other substance to a river, or otherwise making changes affecting the environment. Some of these changes cause obvious effects on flora and fauna, for example when species or communities are simply eliminated. Sometimes there may be replacement of native fauna or flora by less desirable or undesirable species, such as carp. Sometimes more subtle changes occur, such as in species composition of the community. During short periods of study, one sometimes finds great differences in species composition or in total community size, and the question arises whether the differences are caused by man's manipulation, or whether they represent seasonal or long-term changes in fish populations. In view of schooling behavior, chance differences too, can be prominent in fish studies, particularly when sample sizes are small.

For comparative purposes it seems appropriate to examine rather long-term collecting data from an area which has not been subjected to undue physical changes during that period. Such an area occurs in Vigo County, Indiana, below Otter Creek Dam (Markles Dam). The dam was originally built in 1816, and was operative until 1938, when the accompanying mill burned. Since 1962, when the present collections were begun, no changes have occurred which appear to have affected the site in any major way. Just below the dam is a rather deep pool, then an area of smooth rock bottom, followed by a gravel riffle area,

At the lower end of the study site is another pool. The dam has resulted in water continually flowing over the smooth rock and riffles, keeping sand and silt from accumulating here. This continual cleansing action helps to maintain the stability of the area. The existence of rock, gravel, sand and silt bottomed areas in combination with variable water speed and depth causes this to be one of the most ecologically diverse sites in the area. Also, the stream is fairly large (about 70' wide) so includes large numbers of individuals.

The purpose of this paper is to assess variation in fish population levels and community structure at Otter Creek Dam.

Materials and Methods

Seining occurred periodically between 16 November 1962 and 11 September 1974. Between 1 and 4 collections were made per year except in 1970, when no collections were made. In all collections, seining began in the lower pool, extended through the riffles and bedrock and ended at the upper pool, just below the dam. A fifteen foot seine was used in ten of the earlier collections, while a 30 foot seine was used in the rest. The objectives each trip were to secure and identify as many fish as possible. Seine size and personnel differed between trips, but the author was present on all trips, and attempted to ensure collecting uniformity. A few of the values are estimates rather than actual counts, but are thought to be reasonably accurate. Values were converted to percent of sample to indicate species composition between samples. A total of 28 samples was collected, 1 in 1962, 3 in 1963, 3 in 1964, 3 in 1965, 3 in 1966, 4 in 1967, 3 in 1968, 2 in 1969, 2 in 1971, 2 in 1972, 1 in 1973, and 1 in 1974. Monthly samples were distributed as follows: April (3), May (1), June (1), July (4), August (1), September (10), October (2), November (5), and December (1).

Results

A total of 57 species of fish was taken, or 52.8% of the 108 species of fish known to occur or to have occurred in Vigo County. Numbers of individuals totalled 21,029, averaging 751.0 per collection. The species are listed in Table 1, along with their average number per collection, and percentage of collections in which they occurred.

It seemed of interest to determine the number of new species (not taken previously at the dam) occurring in successive collections, thus giving some idea of how many collections were needed before essentially all the species regularly occurring had been taken. Numbers of new species in successive collections are given in Table 2 both for regularly occurring species, and for accidentals.

Of the 57 species taken, those occurring in at least three collections and represented by at least 5 individuals were considered as of "regular" occurrence. Species not fulfilling these criteria were termed as "accidentals". Twenty-one species were accidentals, the last 20 species in Table 1, and *Pomoxis annularis*. The accidentals constituted 36.8% of the total species taken, but only 58 or 0.27 percent of the total number of individuals. Accidentals occurred sporadically through-

TABLE 1. List of fish taken in 28 collections during a 12 year period at Otter Creek Dam, Vigo County, Indiana. Species are listed in order of decreasing number taken.

	Total Number	Av. No. / Collection	No. of Coll.	% Freq.
<i>Pimephales notatus</i> -----	5192	185.4	27	96.4
<i>Notropis chrysocephalus</i> -----	3897	139.2	26	92.9
<i>Notropis spilopterus</i> -----	2958	105.6	25	89.3
<i>Notropis atherinoides</i> -----	1964	70.1	21	75.0
<i>Campostoma anomalum</i> -----	1452	51.9	26	92.9
<i>Hybognathus nuchalis</i> -----	1069	38.2	20	71.4
<i>Ericymba buccata</i> -----	599	21.4	26	92.9
<i>Etheostoma blennioides</i> -----	542	19.4	28	100.0
<i>Etheostoma caeruleum</i> -----	474	16.9	27	96.4
<i>Notropis umbratilis</i> -----	403	14.4	25	89.3
<i>Etheostoma nigrum</i> -----	371	13.3	23	82.1
<i>Phenacobius mirabilis</i> -----	351	12.5	23	82.1
<i>Semotilus atromaculatus</i> -----	287	10.3	18	64.3
<i>Noturus miurus</i> -----	274	9.8	21	75.0
<i>Hypentelium nigricans</i> -----	191	6.8	21	75.0
<i>Notropis stramineus</i> -----	174	6.2	24	85.7
<i>Lepomis macrochirus</i> -----	144	5.1	19	67.9
<i>Etheostoma flabellare</i> -----	114	4.1	23	82.1
<i>Dorosoma cepedianum</i> -----	76	2.7	15	53.6
<i>Moxostoma crythrum</i> -----	72	2.6	16	57.1
<i>Fundulus notatus</i> -----	55	2.0	15	53.6
<i>Notropis blennius</i> -----	49	1.8	9	32.1
<i>Percina maculata</i> -----	45	1.6	10	35.7
<i>Etheostoma spectabile</i> -----	43	1.5	10	35.7
<i>Micropterus salmoides</i> -----	27	1.0	12	42.9
<i>Notropis rubellus</i> -----	27	1.0	8	28.6
<i>Lepomis cyanellus</i> -----	27	1.0	5	17.9
<i>Pomoxis annularis</i> -----	20	0.7	1	3.6
<i>Lepomis megalotis</i> -----	18	0.6	8	28.6
<i>Labidesthes sicculus</i> -----	13	0.5	4	14.3
<i>Catostomus commersoni</i> -----	12	0.4	8	28.6
<i>Notemigonus chrysolaucus</i> -----	11	0.4	6	21.4
<i>Esox americanus</i> -----	11	0.4	6	21.4
<i>Micropterus dolomieu</i> -----	8	0.3	5	17.9
<i>Lepomis humilis</i> -----	7	0.3	6	21.4
<i>Notropis volucellus</i> -----	7	0.3	5	17.9
<i>Pomoxis nigromaculata</i> -----	7	0.3	4	14.3
<i>Hybopsis micropogon</i> -----	6	0.2	2	7.1
<i>Carpionodes cyprinus</i> -----	4	0.1	3	10.7
<i>Notropis boops</i> -----	4	0.1	3	10.7
<i>Micropterus punctulatus</i> -----	3	0.1	3	10.7
<i>Hybopsis storeriana</i> -----	3	0.1	1	3.6
<i>Ambloplites rupestris</i> -----	2	0.1	2	7.1
<i>Ictalurus melas</i> -----	2	0.1	2	7.1
<i>Cyprinus carpio</i> -----	2	0.1	2	7.1
<i>Minytrema melanops</i> -----	1	0.04	1	3.6
<i>Chrosomus erythrogaster</i> -----	1	0.04	1	3.6
<i>Percina caprodes</i> -----	1	0.04	1	3.6
<i>Erimyzon oblongus</i> -----	1	0.04	1	3.6
<i>Lepomis gulosus</i> -----	1	0.04	1	3.6
<i>Moxostoma duquesnii</i> -----	1	0.04	1	3.6
<i>Ichthyomyzon unicuspis</i> -----	1	0.04	1	3.6
<i>Ictiobus niger</i> -----	1	0.04	1	3.6
<i>Carpionodes carpio</i> -----	1	0.04	1	3.6
<i>Moxostoma valenciennesi</i> -----	1	0.04	1	3.6
<i>Lepomis microlophus</i> -----	1	0.04	1	3.6
<i>Ictiobus cyprinella</i> -----	2	0.04	1	3.6

out the collections (Table 2) with 10 occurring in the first half of the collections, and 11 in the second half. Such species cannot be considered very seriously when one is attempting to determine species change of a community through time, and these will not be considered further here.

TABLE 2. Summary data for 28 collections from Otter Creek Dam, Vigo County.

Collection	No. of Species	No. of individuals	First occurrence of species		
			Regular sp.	Accidental	
1 Nov. 62	24	495	22	3	25
2 May 63	9	256	2	—	2
3 Sept. 63	18	557	2	—	2
4 Dec. 63	19	2446	2	—	2
5 July 64	22	235	—	—	0
6 Oct. 64	21	760	1	1	2
7 Nov. 64	25	2482	—	1	1
8 June 65	21	1049	1	—	1
9 Sept. 65	27	244	1	1	2
10 Nov. 65	33	1109	1	1	2
11 Aug. 66	22	393	3	2	5
12 Sept. 66	22	239	—	1	1
13 Nov. 66	23	5344	—	—	0
14 July 67	22	419	—	—	0
15 July 67	22	245	1	—	1
16 July 67	18	317	—	—	0
17 Nov. 67	25	829	—	1	1
18 Apr. 68	16	63	—	1	1
19 Sept. 68	21	152	—	2	2
20 Oct. 68	17	147	—	—	0
21 Apr. 69	12	52	—	1	1
22 Sept. 69	23	87	—	—	0
23 Apr. 71	20	307	—	—	0
24 Sept. 71	26	593	—	1	1
25 July 72	24	651	—	—	0
26 Sept. 72	25	665	—	1	1
27 Sept. 73	25	519	—	3	3
28 Sept. 74	23	374	—	1	1
			36	21	57

Of the regularly occurring species, 28, or 77.8% had been taken by the fourth collection, 35, or 97.2% had been taken by the 11th collection, and all had been taken by the 15th collection.

The most abundant species taken at the dam was *Pimephales notatus*, the bluntnose minnow, and this was one of the four most abundant species in streams of Vigo County (Whitaker and Wallace, 1972). The other species most abundant in Vigo County were *Ericymba buccata*, *Semotilus atromaculatus*, and *Camptostoma anomalum*, these being respectively the 5th, 7th, and 13th most abundant species at Otter Creek Dam. All of the more common stream species of Vigo County were regular inhabitants at the site.

One of the factors contributing to the high number of species at Otter Creek Dam is its proximity to the Wabash River, it being only

about three miles from the River; also it contains some mud and sandy bottomed area and some of the water is quite deep, conditions similar to that of the river. The four most abundant small species of the Wabash River in Vigo County are *Notropis atherinoides*, *N. blennius*, *N. spilopterus*, and *Pimephales vigilax*. *Notropis spilopterus* and *N. atherinoides* were prominent at the dam, being the third and fourth most abundant species there, and *N. blennius* was also of regular occurrence.

Another factor helping to create conditions in which a large species diversity can exist is the presence of the permanent gravelrock association at this locality. This has existed for over 150 years, beginning with the construction of the dam. Thus, a species which exists on this type of habitat and happened at some time to have made its way to the dam would have been able to find permanent, stable habitat. In most other areas in Vigo County, one might find gravel-rock at one time, but later it might be covered with sand and silt. I have observed this in Vigo County on several occasions, particularly in upper Otter Creek, and in Brouillettes Creek.

Some of the darters, particularly *Etheostoma blennioides*, *E. caeruleum*, and *Percina maculata*, the madtom, *Noturus miurus*, and the minnows, *Notropis chrysocephalus*, and *N. umbratilus* are species that are partial to the gravel-rock type of habitat.

Thus it would appear that four main conditions, the large size of the stream, proximity to the river, stable gravel-rock habitat and habitat diversity have contributed to the species diversity found at the dam.

Most localities have few species which occur in adequate abundance so that they are taken in most collections. This locality has 18 species (the first 18 listed in Table 1) easily classed in that group (using criteria as follows; total of over 100 individuals taken, and in at least 18 collections).

Species occurrence and abundance

Only one species, the greenside darter, occurred in all 28 collections. Two species, *Pimephales notatus* and *Etheostoma caeruleum* were taken in 27 collections, while an additional three species occurred in 26; they were *Notropis chrysocephalus*, *Camptostoma anomalum*, and *Ericymba buccata*. Occurrence and abundance of the "major" species throughout the 28 collections is given in Table 3. Also, so that some index of community structure can be obtained, the percentage of individuals that each of these species forms of the total collection is given in parentheses.

It would seem that numbers of fish per collection of the various species might be reasonably similar in view of the habitat stability; however, there is great variation in the total numbers of fish taken per collection (Table 4), and in the numbers of individuals per collection of the various species. The biggest collection was made in November, 1966 (5344 fish) while the smallest was made in April 1969 (when only 52 fish were taken).

TABLE 3. Occurrence and abundance of "major" species at Otter Creek Dam over 29 collections made during a twelve year period. The first numbers are the actual or estimated numbers of fish taken in the sample. Fish species are referred to by initial and are the first 18 species listed in Table 1.

Date	Species						
	P.n.	N.c.	N.s.	N.a.	C.a.	H.n.	E.b. E.c.
Nov 62	80 (16.2)	15 (3.0)	10 (2.0)	0	12 (2.4)	0	17 (3.4) 80 (16.2)
May 63	60 (23.4)	15 (5.8)	0	0	0	0	80 (31.3)
Sept 63	80 (14.4)	0	1 (0.002)	0	80 (14.4)	0	20 (3.6)
Dec 63	600 (24.5)	950 (38.8)	0	13 (0.5)	570 (23.3)	2 (0.1)	41 (1.7) 28 (1.1)
July 64	14 (6.0)	32 (13.6)	70 (29.8)	26 (11.1)	11 (4.7)	0	4 (1.7)
Oct 64	120 (15.9)	75 (9.9)	80 (10.5)	80 (10.5)	110 (14.5)	0	65 (8.6) 15 (2.0)
Nov 64	142 (5.7)	1693 (68.2)	305 (12.3)	151 (6.1)	3 (0.1)	7 (0.3)	87 (3.5) 7 (0.3)
June 65	16 (1.5)	177 (16.9)	465 (44.3)	246 (23.4)	4 (0.4)	58 (5.5)	14 (1.3) 8 (0.8)
Sept 65	28 (11.5)	3 (1.2)	102 (41.8)	29 (11.9)	3 (1.2)	27 (11.1)	3 (1.2) 5 (2.0)
Nov 65	233 (21.0)	51 (4.6)	265 (23.9)	253 (22.8)	33 (3.0)	33 (3.0)	9 (0.8) 25 (2.3)
Aug 66	42 (10.7)	14 (3.6)	67 (17.0)	0	21 (5.3)	70 (17.8)	39 (9.9) 12 (3.1)
Sept 66	99 (41.4)	30 (12.6)	25 (10.5)	0	4 (1.7)	6 (2.5)	3 (1.3) 8 (3.3)
Nov 66	3317 (62.1)	668 (12.5)	576 (10.8)	1 (0.01)	542 (10.1)	38 (0.7)	65 (1.2) 9 (0.2)

July 67	7 (1.7)	19 (4.5)	109 (26.0)	167 (39.9)	12 (2.9)	40 (9.5)	6 (1.4)	7 (1.7)	2 (0.5)
July 67	10 (4.1)	3 (1.2)	35 (14.3)	88 (35.9)	1 (0.4)	17 (6.9)	4 (1.6)	15 (6.1)	15 (6.1)
July 67	35 (11.0)	9 (2.8)	50 (15.8)	130 (41.0)	2 (0.6)	37 (15.1)	17 (6.9)	3 (0.9)	5 (1.5)
Nov 67	0	9 (1.1)	40 (4.8)	608 (73.3)	7 (0.8)	14 (1.7)	34 (4.1)	26 (3.1)	24 (2.9)
Apr 68	10 (15.9)	9 (14.3)	10 (15.8)	3 (4.7)	1 (1.5)	0	4 (6.3)	1 (1.5)	5 (7.9)
Sept 68	4 (2.6)	1 (0.1)	6 (3.9)	50 (32.9)	1 (0.1)	39 (25.7)	13 (8.6)	5 (3.3)	15 (9.9)
Oct 68	18 (12.2)	1 (0.1)	0	33 (22.4)	1 (0.6)	15 (10.2)	1 (0.6)	18 (12.2)	33 (22.4)
Apr 69	9 (17.3)	2 (3.8)	1 (1.9)	0	0	0	0	10 (19.2)	15 (28.8)
Sept 69	12 (13.8)	1 (1.1)	1 (1.1)	1 (1.1)	2 (2.3)	6 (6.9)	4 (4.6)	7 (8.0)	15 (17.2)
Apr 71	50 (16.3)	50 (16.3)	40 (13.0)	1 (0.3)	3 (1.0)	0	30 (9.8)	15 (4.9)	10 (3.3)
Sept 71	35 (5.9)	6 (1.0)	100 (16.9)	40 (6.7)	4 (0.7)	250 (42.2)	2 (0.3)	15 (2.5)	20 (3.4)
July 72	35 (5.4)	0	100 (15.4)	2 (0.3)	4 (0.6)	200 (30.7)	20 (3.1)	50 (7.7)	3 (0.5)
Sept 72	100 (15.0)	10 (1.5)	75 (11.3)	0	15 (2.3)	150 (22.6)	10 (1.5)	30 (4.5)	15 (2.3)
Sept 73	35 (6.7)	50 (9.6)	200 (38.5)	40 (7.7)	2 (0.4)	20 (3.9)	2 (0.4)	40 (7.7)	20 (3.9)
Sept 74	1 (0.3)	4 (1.1)	225 (60.2)	2 (0.5)	4 (1.1)	40 (10.7)	1 (0.3)	6 (1.6)	0

TABLE 3. (cont.)

Date	N.u.	E.n.	P.m.	Species		H.n.	N.s.	L.m.	E.f.
Nov 62	0	40 (8.0)	10 (2.0)	20 (4.0)	16 (3.2)	8 (1.6)	7 (1.4)	25 (5.0)	8 (1.6)
May 63	5 (1.9)	0	0	0	0	0	0	0	5 (1.9)
Sept 63	20 (3.6)	20 (3.6)	65 (11.7)	40 (7.2)	5 (0.9)	60 (10.8)	20 (3.6)	15 (2.6)	5 (0.9)
Dec 63	5 (0.2)	9 (0.4)	190 (7.8)	9 (0.4)	1 (.04)	7 (0.03)	0	0	1 (0.04)
July 64	10 (4.3)	11 (4.7)	0	7 (3.0)	1 (0.4)	1 (0.4)	1 (0.4)	1 (0.4)	1 (0.4)
Oct 64	55 (7.2)	15 (2.0)	15 (2.0)	43 (5.7)	1 (0.1)	0	15 (2.0)	15 (2.0)	0
Nov 64	13 (0.5)	5 (0.2)	7 (0.3)	24 (1.0)	0	0	6 (0.2)	4 (0.2)	3 (0.1)
June 65	19 (1.8)	5 (0.5)	1 (0.1)	7 (0.7)	1 (0.1)	1 (0.1)	4 (0.4)	4 (0.4)	1 (0.1)
Sept 65	11 (4.5)	8 (3.3)	0	0	3 (1.2)	1 (0.4)	1 (0.4)	6 (2.5)	1 (0.4)
Nov 65	51 (4.6)	13 (1.2)	1 (0.1)	30 (2.7)	1 (0.1)	3 (0.3)	34 (3.1)	8 (0.7)	19 (1.7)
Aug 66	29 (7.4)	7 (1.8)	3 (0.8)	17 (4.3)	2 (0.5)	4 (1.0)	4 (1.0)	13 (3.3)	10 (2.5)
Sept 66	14 (5.9)	5 (2.1)	1 (0.4)	17 (7.1)	5 (2.1)	4 (1.7)	2 (0.8)	6 (2.5)	0
Nov 66	38 (0.7)	0	10 (0.2)	42 (0.8)	0	2 (.04)	13 (0.2)	5 (0.1)	1 (0.01)

July 67	0	1	5	0	2	4	3	2	2
	(0.2)	(1.2)	(1.2)	(0.5)	(1.0)	(0.7)	(0.5)	(0.5)	(0.5)
July 67	25	3	5	0	5	4	4	2	0
	(10.2)	(1.2)	(2.0)	(2.0)	(2.0)	(1.6)	(0.8)	(0.8)	
July 67	2	0	9	2	0	1	0	0	1
	(0.6)	(2.8)	(6.6)	(0.3)	(0.3)				(0.3)
Nov 67	2	8	1	3	2	0	1	13	6
	(0.6)	(1.0)	(0.1)	(3.6)	(0.2)		(0.1)	(1.6)	(0.7)
Apr 68	7	0	2	0	0	0	6	0	1
	(0.1)	(3.2)	(0.6)				(9.5)		(1.5)
Sept 68	1	0	4	0	0	4	1	0	0
	(0.1)	(2.6)				(2.6)	(0.1)		
Oct 68	2	6	1	0	2	0	1	2	10
	(1.4)	(4.1)	(0.6)		(1.4)		(0.6)	(1.4)	(6.8)
Apr 69	4	1	5	0	0	0	0	0	1
	(7.7)	(1.9)	(9.6)						(1.9)
Sept 69	0	9	3	2	1	9	2	2	1
		(10.3)	(3.4)	(2.3)	(1.1)	(10.3)	(2.3)	(2.3)	(1.1)
Apr 71	22	35	3	5	1	3	25	0	8
	(7.2)	(11.4)	(1.0)	(1.6)	(0.3)	(1.0)	(8.1)		(2.6)
Sept 71	23	6	3	2	15	15	1	3	10
	(3.9)	(1.0)	(0.5)	(0.3)	(2.5)	(2.5)	(0.2)	(0.5)	(1.7)
July 72	15	60	6	2	70	15	10	0	0
	(2.3)	(9.2)	(0.9)	(0.3)	(10.8)	(2.3)	(1.5)		
Sept 72	20	75	1	15	100	20	5	0	3
	(3.0)	(11.3)	(0.2)	(2.3)	(15.0)	(3.0)	(0.8)		(0.5)
Sept 73	7	10	0	0	30	15	4	10	10
	(1.3)	(1.9)			(5.8)	(2.9)	(0.8)	(1.9)	(1.9)
Sept 74	3	19	0	0	10	10	4	8	6
	(0.8)	(5.1)			(2.7)	(2.7)	(1.1)	(2.1)	(1.6)

TABLE 4. "Major" fish species at Otter Creek Dam in 28 collections in a twelve-year period. The first values are the actual numbers of fish in the sample, the second are the percent of that sample.

	Nov '62	May '62	Sept '63	Dec '63	July '64	Oct '64	Nov '64	June '65	Sept '65	Nov '65	Aug '66	Sept '66	Nov '66	July '66
<i>P. notatus</i>	80 16.2	60 23.4	80 14.4	600 24.5	14 6.0	120 15.9	142 5.7	16 1.5	28 11.5	233 21.0	42 10.7	99 41.4	3317 62.1	7 1.7
<i>N. chrysocephalus</i>	15 3.0	15 5.8	0	950 38.8	32 13.6	75 9.9	1693 68.2	177 16.9	3 1.2	51 4.5	14 3.6	30 12.6	668 12.5	19 4.5
<i>N. spilopterus</i>	10 2.0	0	1 .002	0	70 29.8	80 10.5	305 12.3	465 44.3	102 41.8	265 23.9	67 17.0	25 10.5	576 10.8	109 28.0
<i>N. atherinoides</i>	0	0	0	13 0.5	26 11.1	80 10.5	151 6.1	246 23.4	29 11.9	253 22.8	0	0	1 0.01	167 39.9
<i>C. anomalum</i>	12 2.4	0	80 14.4	570 23.3	11 4.7	110 14.5	3 0.1	4 0.4	3 1.2	33 3.0	21 5.3	4 1.7	542 10.1	12 2.9
<i>H. nuchalis</i>	0	0	0	2 0.1	0	0	7 0.3	58 5.5	27 11.1	33 3.0	70 17.8	6 2.5	38 0.7	40 9.5
<i>E. buccata</i>	17 3.4	0	80 14.4	41 1.7	28 11.9	65 8.6	87 3.5	14 1.3	3 1.2	9 0.8	39 9.9	3 1.3	65 1.2	6 1.4
<i>E. blennioides</i>	80 16.2	80 31.3	20 3.6	28 1.1	4 1.7	15 2.0	7 0.3	8 0.8	3 1.2	25 2.3	12 3.1	3 1.3	9 0.2	2 1.7

E.	80	80	20	11	4	15	15	6	5	26	6	8	1	2
caeruleum	16.2	31.3	3.6	0.4	1.7	2.0	0.6	0.6	2.0	2.3	1.5	3.3	0.01	0.5
N.	0	5	20	5	10	55	13	19	11	51	29	14	38	0
umbrae		1.9	3.6	0.2	4.3	7.2	0.5	1.8	4.5	4.6	7.4	5.9	0.7	
E.	40	0	20	9	11	15	5	5	8	13	7	5	0	1
nigrum	8.0		3.6	0.4	4.7	2.0	0.2	0.5	3.3	1.2	1.8	2.1		0.2
P.	10	0	65	190	0	15	7	1	0	1	3	1	10	5
mirabilis	2.0		11.7	7.8		2.0	0.3	0.1		0.1	0.8	0.4	0.2	1.2
S.	20	0	40	9	7	43	24	7	0	30	17	17	42	0
atromaculatus	4.0		7.2	0.4	3.0	5.7	1.0	0.7		2.7	4.3	7.1	0.8	
N.	16	0	5	1	1	1	0	1	3	1	2	5	0	2
miurus	3.2		0.9	.04	0.4	0.1		0.1	1.2	0.1	0.5	2.1		0.5
H.	8	0	60	7	1	0	0	1	1	3	4	4	2	4
nigricans	1.6		10.8	0.03	0.4			0.1	0.4	0.3	1.0	1.7	.04	1.0
N.	7	0	20	0	1	15	6	4	1	34	4	2	13	3
stramineus	1.4		3.6		0.4	2.0	0.2	0.4	0.4	3.1	1.0	0.8	0.2	0.7
L.	25	0	15	0	1	15	4	4	6	8	13	6	5	2
macrochirus	5.0		2.6		0.4	2.0	0.2	0.4	2.5	0.7	3.3	2.5	0.1	0.5
E.	8	5	5	1	1	0	3	1	1	19	10	0	1	2
flabellare	1.6	1.9	0.9	0.04	0.4	0.1	0.1	0.1	0.4	1.7	2.5		0.01	0.5

TABLE 4. (cont.)

	July '67	July '67	Nov '67	Apr '68	Sept '68	Oct '68	Apr '69	Sept '69	Apr '71	Sept '71	July '72	Sept '72	Sept '73	Sept '74
<i>P. notatus</i>	10 4.1	35 11.0	0	10 15.9	4 2.6	18 12.2	9 17.3	12 13.8	50 16.3	35 5.9	35 5.4	100 15.0	35 6.7	1 0.3
<i>N. chrysocephalus</i>	3 1.2	9 2.8	9 1.1	9 14.3	1 0.1	1 0.1	2 3.8	1 1.1	50 16.3	6 1.0	0	10 1.5	50 9.6	4 1.1
<i>N. spilopterus</i>	35 14.3	50 15.8	40 4.8	10 15.8	6 3.9	0	1 1.9	1 1.1	40 13.0	100 16.9	100 15.4	75 11.3	200 38.5	255 60.2
<i>N. atherinoides</i>	88 35.9	130 41.0	608 73.3	3 4.7	50 32.9	33 22.4	0	1 1.1	1 0.3	40 6.7	2 0.3	0	40 7.7	2 0.5
<i>C. anomalum</i>	1 0.4	2 0.6	7 0.8	1 1.5	1 0.1	7 0.6	0	2 2.3	3 1.0	4 0.7	4 0.5	15 2.3	2 0.4	4 1.1
<i>H. nuchalis</i>	17 6.9	37 15.1	14 1.7	0	39 25.7	15 10.2	0	6 6.9	0	250 42.2	200 30.7	150 22.6	20 3.9	40 10.7
<i>E. buccata</i>	4 1.6	17 6.9	34 4.1	4 6.3	13 8.6	1 0.6	0	4 4.6	30 9.8	2 0.3	20 3.1	10 1.5	2 0.4	1 0.3
<i>E. biennioides</i>	15 6.1	3 0.9	26 3.1	1 1.5	5 3.3	18 12.2	10 19.2	7 8.0	15 4.9	15 2.5	50 7.7	30 4.5	40 7.7	6 1.6

E.	15	5	24	5	15	33	15	15	10	20	3	15	20	0
caeruleum	6.1	1.5	2.9	7.9	9.9	22.4	28.8	17.2	3.3	3.4	0.5	2.3	3.9	
N.	25	2	2	7	1	2	4	0	22	23	15	20	7	3
umbratilis	10.2	0.6	0.2	0.1	0.1	1.4	7.7		7.2	3.9	2.3	3.0	1.3	0.8
E.	3	0	8	0	0	6	1	9	35	6	60	75	10	19
nigrum	1.2		1.0			4.1	1.9	10.3	11.4	1.0	9.2	11.3	1.9	5.1
P.	5	9	1	2	4	1	5	3	3	3	6	1	0	0
mirabilis	2.0	2.8	0.1	3.2	2.6	0.6	9.6	3.4	1.0	0.5	0.9	0.2		
S.	0	2	3	0	0	0	0	2	5	2	2	15	0	0
atromaculatus		0.6	3.6					2.3	1.6	0.3	0.3	2.3		
N.	5	0	2	0	0	2	0	1	1	15	70	100	30	10
miurus	2.0		0.2			1.4		1.1	0.3	2.5	10.8	15.0	5.8	2.7
H.	4	1	0	0	4	0	0	9	3	15	15	20	15	10
nigricans	1.6	0.3			2.6			10.3	1.0	2.5	2.3	3.0	2.9	2.7
N.	4	0	1	6	1	1	0	2	25	1	10	5	4	4
stramineus	1.6		0.1	9.5	0.1	0.6		2.3	8.1	0.2	1.5	0.8	0.8	1.1
L.	2	0	13	0	0	2	0	2	0	3	0	0	10	8
macrochirus	0.8		1.6			1.4		2.3		0.5			1.9	2.1
E.	0	1	6	1	0	10	1	1	8	10	0	3	10	6
fiabellare		0.3	0.7	1.5		6.8	1.9	1.1	2.6	1.7		0.5	1.9	1.6

Further indication of the changing nature of the fish-community is the lack of consistency of the most abundant species in the 28 collections. (More than 28 entries are recorded, since there were several cases of ties between two or three species as most abundant). If a major degree of consistency was maintained, one would expect the same or little change in the most abundant species between collections. *Notropis spilopterus* and *Pimephales* were classed as most abundant 7 times each, *Notropis atherinoides* 6, *Etheostoma caeruleum* 5, *Notropis chrysocephalus* and *Hybognathus nuchalis* 3 each, *Etheostoma blennioides* and *Ericymba buccata* 2 each, and *Campostoma anomalum* one. Thus, 9 different species were the most abundant fish (or in a tie for this) at least once during the study. *Notropis atherinoides* was most abundant 4 times in a row (summer and fall of 1967), while *Hybognathus nuchalis* was high three times in a row (between September 1971 and September 1972).

Some of the more important species are discussed below. To indicate seasonal variation, for each species four values are given, designating respectively early spring (April-May), summer (June-August), fall (September-October), and winter (November-December).

Pimephales notatus 32.3, 22.7, 48.4, 728.7

This was the most abundant species present, and was taken in all but one collection. It is interesting that the collection from which it was absent was of above average size (829 individuals taken). There were pronounced seasonal differences in this species, with the largest number being taken in fall and winter. However, within these time periods, there was much variation, particularly in November-December, which yielded the largest number of individuals in any one collection, 3317 in November 1966. This species comprised 62.1% of the sample. Just a year later, it was not taken at all, for reasons unknown. It seems noteworthy that two other species also declined markedly between these two collections, *N. chrysocephalus* and *N. spilopterus*. One individual of *N. atherinoides* was taken in November 1966, while 608 (73.3% of the sample) were taken in November, 1967.

Notropis chrysocephalus 19.0, 36.3, 16.5, 564.3

The second most abundant species over the entire study was *Notropis chrysocephalus*. For this species, November-December was the period of greatest abundance (range 9-1693), followed by June-August, April-May, and with September-October being the poorest (0-75). Its occurrence was erratic, with 15 being taken during November and May of 1962 and 1963, none in September 1963, and then 950 in December 1963. It declined in July and October 1964, but in December, 1963 were collected. Again in September 1966, 30 were taken. It would appear that this species was affected by seasonal factors, with late fall and early winter favoring concentrations of the species at the dam. Unknown factors played a major role, leading to erratic changes in populations.

Notropis spilopterus 12.8, 128.0, 74.1, 199.2

Again population highs occurred in early winter, while the low occurred in early spring. The second largest collection was in summer,

but seasonal variation was not as great in this species as in some others. This species appeared to be somewhat cyclic. It was taken at rates of 0 to 10 over the first four collections. Larger numbers were taken between July 1964 and November 1967, then dropped to 10, 6, 0, 1 and 1 between April 1968 and September 1969. Then numbers taken again increased and were rather high for all the rest of the collections.

Notropis atherinoides 1.0, 94.1, 25.0, 171.0

Again winter was the time of greatest numbers of individuals. Like *N. spilopterus*, this species also showed a long term cyclic turnover, but it was much more distinct. The first three collections yielded no *N. atherinoides*. Then in December 1963, 13 were taken, followed by continued increase through November, 1965, with the exception that in September, 1965, the catch was low. This was followed by low numbers in August and September 1966. Only 1 was taken in November 1966, followed by another period of highs. Thus it appeared that this species had less erratic population levels than some of the other species, that there was a weak seasonal affect, but that it appeared to be strongly affected by long-term changes in population levels.

Camptostoma anomalum 1.0, 7.9, 20.5, 194.5

In this species, seasonal effects were pronounced, with greater numbers of fishes taken later in the season (Chi-square = 3027.9, 3 df). Individuals were taken in all collections but two of the early spring collections and usually in fairly low numbers. There were two very large collections (570 on 5 December 1963, and 542 on 3 November 1966) and two somewhat large collections (110 on 5 October, 1964, and 80 on 23 September 1963), but there was no general cyclic type pattern in the collection data for this species. Rather, the large collections occurred erratically, with large numbers of fish in schools, perhaps migratory.

Hybognathus nuchalis 0, 60.3, 50.3, 15.8

Unlike the species discussed previously, largest numbers of this species were taken in summer, followed by September-October. No silvery shiners were taken in early spring. There was some indication of long term population changes, but it was not strongly marked. Only two individuals were taken in the 6 collections through 5 October 1964. The species occurred at moderate levels in all collections but one through 24 October 1968. Only 6 individuals were taken in the next three collections (but two were in spring), then it occurred in its largest numbers in the three collections in 1972 and 1973, averaging 200 per collection, as compared to 18.8 in the other 25 collections. The biggest number taken in any other single collection during the study was 70 (3 August 1966).

Ericymba buccata. 8.5, 18.3, 16.7, 42.3

This species was found in all but two collections. Greatest numbers were taken in fall-winter, but numbers per collections during the other periods were not great. The silverjaw minnow was present throughout the study period, without showing pronounced increases or decreases although the numbers taken in the earlier 14 collections

averaged larger at 32.6 per collection, than the last 14 collections (10.1).

Etheostoma blennioides 26.5, 14.1, 14.7, 29.2

Populations of this species were highest in the spring, late fall and winter, and somewhat lower in summer and early fall, although the differences were not great. This is the only species that was taken in every collection (range of 1 to 80 individuals). There were no markedly large collections, nor no apparent rhythmic oscillations in numbers.

Etheostoma caeruleum 27.5, 5.9, 15.1, 26.2

The occurrence of this species in collections was very similar to that of *E. blennioides* in every respect (even the totals taken were quite close, 542 vs. 474).

Notropis umbratilus 9.5, 14.3, 14.2, 18.2

There was relatively little seasonal variation in this species, and the species occurred in nearly all collections (25). There may have been some long-term population changes, as slightly higher numbers were taken September 1963 through November 1966, and April 1971 through September 1972 than at other periods.

Etheostoma nigrum 9.0, 12.4, 15.7, 12.5

There were no exceedingly large collections, nor was there clear evidence of any rhythmic population fluctuations. The species was of regular occurrence being taken in 23 of the 28 collections. Catches of this species were quite similar during the four time periods, indicating little seasonal change in populations.

Phenacobius mirabilis 2.5, 4.1, 8.5, 36.5

This species generally occurred in low numbers and was taken in 23 of the 28 collections. However, in two consecutive collections, 23 September and 5 December 1963, 65 and 190 suckermouth minnows were taken. Apparently there was a buildup of the species that year, perhaps due to good environmental conditions for reproduction. Many more fish of this species were taken in winter than at other times.

Semotilus atromaculatus 1.3, 5.0, 10.1, 21.3

Semotilus atromaculatus was taken in increased numbers later in the season. This species was rather peculiar in its distribution throughout the collecting period. Creek chubs were taken in fairly good numbers and in most of the 13 collections from 1962 through 1966, but only 5 were taken in the 8 collections from July 1967 through April 1969. Small numbers were taken in the next five collections. The significance of these values is not understood.

Noturus miurus 0.3, 11.6, 15.6, 3.3

This species appeared to increase in abundance from spring through fall, then, contrary to many of the species, fell off drastically. However, these figures mean little because of the occurrence of two very large collections, one in July of 1970, and one in September of

about 100 individuals. This species was taken in low numbers in most collections through July of 1972, when about 70 were taken, then in September 1972 about 100 were taken, and by September of 1973 they had dropped off, and about 30 were taken. It is not known what caused the 1972 population increase.

The above discussion includes all fish taken in numbers of more than 200 during the study. Because of their small numbers, the remainder of the species will not be discussed.

Of the more important species, 8 reach their population highs in fall and winter (*P. notatus*, *N. chrysocephalus*, *N. spilopterus*, *N. atherinoides*, *C. anomalum*, *E. buccata*, *P. mirabilis* and *S. atromaculatus*). One, *H. nuchalis*, reached its high in summer, and the two darters, *E. blennioides* and *E. caeruleum* reached population highs in winter and spring.

Four species, *P. notatus*, *N. chrysocephalus*, *C. anomalum*, and *P. mirabilis* each had one rather pronounced population buildup during the study. These could have been the result of exceptionally favorable reproductive conditions one year, producing large year classes. Four species showed cyclic tendencies, *N. atherinoides* strongly, *N. spilopterus* less strongly, and *H. nuchalis* and *N. umbratilis* weakly. It is possible that the high population levels seen in these latter species, are simply two erratic type highs in close succession. Longer term data are needed to determine whether this pattern is recurrent.

The composition of the five larger collections (those in which more than 1000 individuals were taken) was examined to determine if one or a few species made up most of the individuals, and also if the two river species, *N. spilopterus* and *N. atherinoides* increased and decreased together. These collections occurred in December 1963, November 1964, June 1965, November 1965 and November 1966. *Notropis chrysocephalus* and *N. spilopterus* were each the most abundant species in two of these collections, while *P. notatus* was the most abundant in one. *Notropis spilopterus* comprised 44.3% of the fish in the June 1965 collection, while it was not even present in the December 1963 collection. *Notropis atherinoides* ranged from 0.1 to 23.4%. *Notropis spilopterus* and *N. atherinoides* showed some degree of consistency in the five collections, but not much over the 28 collections.

Impressive throughout these data was the lack of similarity between collections. It seems obvious that even in a stream in which environmental changes over a period of time are minimal, there may be extensive changes in the fish community. For this reason one should be cautious in using short term data to draw conclusions concerning the relationship of some variable, such as heat or a chemical additive to a community. Such changes may well be normal community changes such as those discussed which are in no way related to the variable of interest.

A Biotic Inventory of the Dobbs Park Natural Area

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Abstract

Dobbs Park is a 105-acre (42-hectare) tract, located at the east edge of Terre Haute, Indiana. Community types range from grass-forb to a 14-acre old-growth deciduous forest.

The old-growth is largely upland depressional, much of which is subject to periodic ponding. Dominants among the 34 tree species present are elms (*Ulmus americana*, *rubra*, and *thomasi*) and ashes (*Fraxinus americana* and *pennsylvanica*) at a combined importance of 33 per cent. A mesic ridge supports beech and sugar maple plus upland oaks and hickories. Total density above 4 inches dbh is 340 stems per hectare (138 per acre); total basal area is 27.5 square meters per hectare (120 square feet per acre); mean stem diameter is 26.7 centimeters (10.5 inches).

The present vascular plant list totals 263 species. The vertebrate fauna includes 16 mammal, 73 bird, 10 reptile, 8 amphibian and 7 bony fish species.

Introduction

The purpose of this study was to complete a biotic inventory of the Dobbs Park natural area. Our data will be used by the Terre Haute Board of Parks and Recreation as a guide in developing Dobbs Park into an environmental education center. Special attention was given to the ecological attributes and distribution patterns of tree species within the old-growth forest. Information obtained for the old-growth community will serve as a data base in a long-term study. Specific objectives follow:

- 1) Inventories of the vascular flora, vertebrate fauna, and vegetation types of the entire park
- 2) Full census of the old-growth forest, plus construction of a 1:33 scale map of exact tree locations.

Study Site

Dobbs Park is located on the east edge of Terre Haute in Vigo County, Indiana, at the junction of Poplar Street and State Road 46, Township 12 N, Range 8 W. The "L"-shaped tract contains 42 ha (105 acres). It is bordered on the south and east by highways and on the north and west by subdivisions and crop fields (Fig. 1).

In 1944, the land was donated to the City of Terre Haute, in the name of John G. Dobbs Memorial Grove, with the stipulation that it be used primarily as a natural area park. In 1975, the old-growth tract and adjacent forested areas totalling about 10 ha (25 acres) was designated as a State Nature Preserve.

The area was formerly a farm with parcels of land left to natural succession at various times in the past, thereby resulting in most upland seral stages. During the middle and late 1940's, the city added a 1-ha lake (2.5 acres) and several pine and a few hard-

wood plantings totalling about 12.5 ha (32 acres). Only the areas surrounding the park entrance, lake and picnic grounds are mowed (Fig. 1).

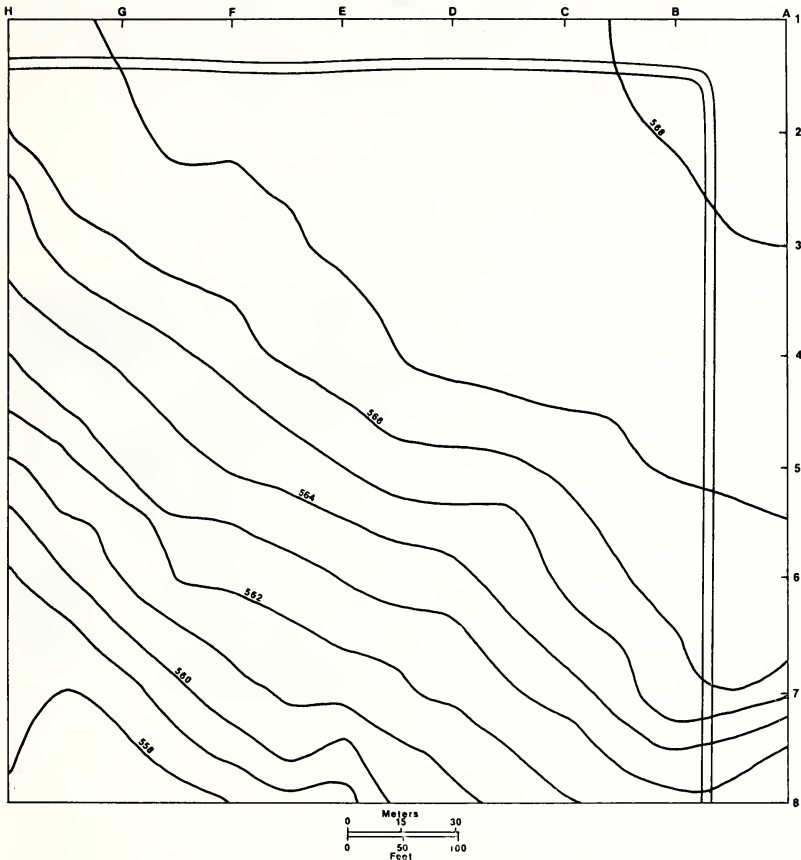


FIGURE 1. Community types map of the Dobbs Park natural area.

The north end of the park contains a 5.6 ha (14-acre) stand of original forest (Figs. 1 and 2). Any cutting has been minimal and a long time ago. Canopy openings were created by recent elm mortality and occasional wind-thrown trees. The only human disturbance of consequence is an abandoned bridle trail which parallels three sides of the area in about 20-30 m from the perimeter (Fig. 2). Since the trail was discontinued in 1971, tree seedlings and herbs have rapidly colonized the trail borders.

Soil parent material is Wisconsinan age loess over Illinoian age glacial till, which in turn, overlays Pennsylvanian age sandstone and shale.

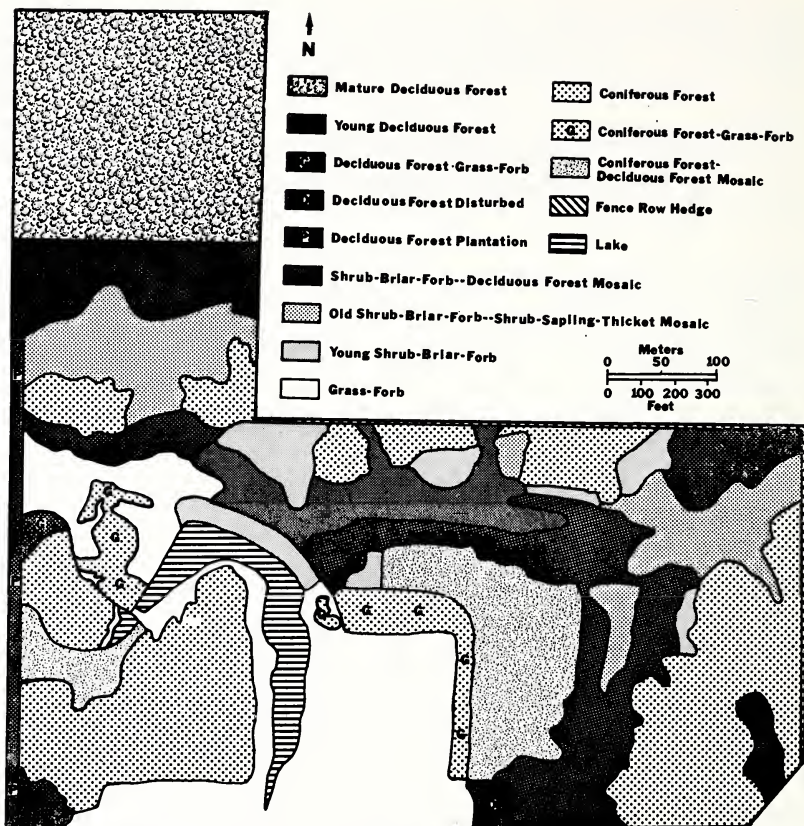


FIGURE 2. Plot layout and relief map of the old-growth section of Dobbs Park natural area. (The shaded strip is an old bridge trail.)

The old-growth section ranges from nearly flat to gently sloping, with a total of about 10 feet of relief (Fig. 2). Poorly-drained Reeseville silt loam (I Profile) predominates. Most of the flatter areas are seasonally ponded, sometimes for 2-3 months.

Successional areas (Fig. 1) have greater relief and more rapid drainage, although overflow and ponding occur locally. Soil types range from Wakeland (II Profile) in the poorly-drained bottom lands to Muren (III), Alford (IV), and Cincinnati (IV) on better-drained upland sites.

Methods

A vegetation map was constructed by delimiting community boundaries on a 1:600 scale aerial photograph flown in 1967. Extensive field reconnaissance and vegetation sampling was required to adjust community boundaries which had changed since 1967. Mapping units were based on physiographic separation, physiognomy of vegetation, floristic composition and seral development. Although the successional

stages blend and approach a continuum, units which differ sufficiently in composition from other such units to be recognized consistently were mapped as separate vegetation types.

Vegetation composition of seral communities was evaluated by the stratum rank method of Lindsey *et al.* (5). Floral collections were made at 3-week intervals or more often. Species new to Vigo County were listed by Jackson *et al.* (4). A faunal list was compiled by sightings or presence definitely established by sign. Fish species within the lake were determined from catches by fishermen during the summers of 1974 and 1975.

Species nomenclature follows Fernald (3) for non-arborescent vascular plants; Little (8) for trees; Lyon (9) for mammals; Peterson (10) for birds; Conant (1) for reptiles and amphibians; and Eddy (2) for bony fishes.

Analysis of the old-growth forest involved the least disturbed section (largely inside of the old bridle trail) totalling 3.6 ha (9 acres) (Fig. 2). Mapping of tree locations was facilitated by gridding the area into 36 0.1-ha plots, each 31.6 m²; these, in turn, were divided east-west into half plots. A 50-meter tape along the south or north side of each half plot served as the base line, from which the distance to each tree was measured by a 15-m retractable loggers tape. A Suunto sighting compass served to establish perpendicular distances from the base line to the trees being plotted. Locations of all trees over 10 cm dbh (diameter breast height) were mapped; seedling positions of American beech (*Fagus grandifolia* Ehrh.) and sugar maple (*Acer saccharum* Marsh.) were also plotted.

Construction of the 1:33 scale map was accomplished by an IBM Model 180 computer. Field data entered into the program was computer plotted within scaled study plot circles corresponding to the scaled dbh at coordinates entered for each tree. For tree identification, the plotter over-printed within each circle the tree species and true dbh. Copies of the computer program are available upon request from the authors.

Results

Plant Communities

Eighteen community types were mapped as 40 mapping units. Figure 1 depicts the major types, but not all individual mapping units.

Four major community types, totalling 25.6 ha (65 acres), have closed or nearly-closed canopies: mature deciduous forest, young deciduous forest, coniferous forest plantations and deciduous forest plantations. The seven units of young deciduous forest total approximately 6.5 ha (16 acres) and contain mostly species that are found within the mature deciduous forest, thereby acting as second growth extensions of the old-growth.

Twelve units of coniferous forest plantations total 12.5 ha (32 acres). These 30-year-old plantings contain varying combinations of red (*Pinus resinosa*), white (*P. strobus*), Scotch (*P. sylvestris*), and Virginia (*P. virginiana*) pines. Many of the plantations contain dead

or dying conifers being shaded out by taller deciduous species, but some natural reproduction also occurs.

Two small deciduous plantations totalling about 1 ha (2.5 acres) contain pure stands of tulip tree (*Liriodendron tulipifera*).

Non-canopied areas of low grass-forb, old field (shrub-briar-forb), and shrub-sapling thicket collectively comprise about 12 ha (30 acres). The grass-forb community is a mixture of short grasses and herbs, held in an early successional stage by mowing. Old field vegetation is a mixture of herbaceous perennials with young shrubs, briars, and tree seedlings. Old field becomes shrub-sapling thicket as development time increases and shrubs and saplings reach 60 per cent or more of the total ground cover.

Table 1 summarizes the stratum rank data of the primary community types. Comprehensive stratum rank data by species for each unit of each community type are available from the authors upon request.

Floral and Faunal Surveys

To date, the floral inventory totals 263 species of vascular plants representing 169 genera and 78 families. This high number of species is a product of great habitat diversity and wide variations in available soil moisture. Active field collection in the future, plus verification of some present collections, should bring the floristic list to over 300 species.

The vertebrate fauna stands at 114 species, including 16 mammals, 73 birds, 10 reptiles, 8 amphibians, and 7 bony fishes. Whitetail deer (*Odocoileus virginiana*) and red and gray foxes (*Vulpes fulva* and *Urocyon cinereoargenteus*) reside within the park and are seen occasionally. The large number of bird records during the 2-year study reflects the excellent mix of vegetation types and abundant nesting sites for resident species. Many migratory species visit the park as they move along the Wabash River migration corridor. Bird records of particular interest or rarity are the red crossbill (*Loxia curvirostra*), pileated woodpecker (*Hylotomus pileatus*) and the great blue heron (*Ardea herodias*). Green herons (*Butorides virescens*) nest within the park. Complete flora and fauna lists are available upon request.

TABLE 1. *Species richness by stratum within the major vegetation units at Dobb's Park (Grass-forb units (Fig. 1) were not stratum ranked because of disturbance due to mowing).*

Community Type	Stratum ¹			
	Canopy	Subcanopy	Shrub	Herbaceous
Mature deciduous forest -----	17	21	30	66
Young deciduous forest -----	20	31	41	69
Coniferous plantation -----	18	18	24	58
Deciduous plantation -----	1	1	13	24
Shrub-sapling thicket -----	—	7	24	41
Old field -----	—	4	14	52

¹ Canopy: >25 cm in diam and >10 m tall; subcanopy: >5 cm in diam and <10 m tall; shrub: >0.5 m tall and <5 cm in diam; herbaceous: <0.5 m tall.

Old-Growth Analysis

The old-growth is dominated by elms (*Ulmus americana*, *rubra* and *thomasii*) and ashes (*Fraxinus americana* and *pennsylvanica*) at collective importance percentages of 18.5 and 14.4, respectively. These co-dominants have relatively high stem densities (97.5 per ha for elm and 56.9 for ash) of medium-sized trees, plus high frequencies (Table 2).

The third species is white oak (*Quercus alba*) at 7.9 per cent importance. A low density of 12 per ha is offset by a large average stem diameter of 66.7 cm. (Table 2).

Total density is 340 stems per ha (138 stems per acre); total basal area is 27.5 m² per ha (120 ft² per acre). The presence of 34 tree species reflects the heterogeneity in soil moisture conditions even though relief varies only 10 feet (Figure 2).

Mean stem diameter is 26.7 cm (10.5 inches), with twelve species containing 52 individuals in or above the 75-cm (30-inch) size class. The ten largest trees (>95 cm or 36-inch) are oaks: Shumard's red (*Quercus shumardii*), northern red (*Q. rubra*), white (*Q. alba*), and chinkapin (*Q. muehlenbergii*) reach maximum diameters of 50.1, 42.2, 41.3 36.0, respectively.

Beech (*Fagus grandifolia*) and sugar maple (*Acer saccharum*) are the seventh and eighth most important species. A well-drained ridge best suited for the growth of mesic species runs roughly from the northwest to the southeast corners of the old-growth. This mesic band contains all the large beech and most large sugar maples.

Discussion

From observations of species distribution patterns, it is apparent that the flat northeast corner of the old-growth has been wet for quite some time (Figure 2). Alteration of natural drainage patterns when the subdivision was built on the north has increased the level and duration of ponding in recent times. With drainage blocked, water stands at varying levels from March through May. Plant distribution patterns correspond very closely to the areas ponded and the moisture tolerances of particular species, as extremes are the factors which control vegetation. Only species of high flood tolerance, such as red maple (*Acer rubrum*) and green ash (*Fraxinus pennsylvanica*) are capable of reproducing within the maximum ponded areas. Differences in soil moisture levels in late summer were not significant, reflecting that it is excessive moisture in the spring, rather than soil drying in the fall, that influences tree species success within mature forests.

Although Dobbs Park is located in the northern part of the Wabash lowland physiographic region, the old-growth is topographically similar to Tipton Tillplain stands, such as Meltzer Woods (7), Beckville Woods (7) and Bryan Nature Preserve (5).

In comparison with these stands, Dobbs Park has about average stand basal area, and a slightly above average stem density (Table 3). The higher stem density at Dobbs is a product of disturbance by wind throw and elm mortality. The light gaps are quickly filled by seedlings of wind-dispersed species, such as sugar maple and American elm.

TABLE 2. Stand attributes for tree species within the mature deciduous forest community of Dobb's Park, Terre Haute, Indiana based on a full census of 3.60 hectares. Frequencies are based on 36 0.1-ha square plots.

Species	Density Per Hectare	Relative Density	Frequency	Relative Frequency	Basal Area per Hectare in M ²	Relative Basal Area	Percent Importance	Mean Diameter in cm
<i>Ulmus americana</i>	67	20	36	8.7	1.2	4.5	11	16.1
<i>Fraxinus americana</i>	44	13	35	8.4	3.1	11	11	27.4
<i>Quercus alba</i>	12	3.5	17	4.1	4.4	16	7.9	66.7
<i>Carya cordiformis</i>	28	8.2	23	5.5	2.2	8.0	7.2	27.2
<i>Liriodendron tulipifera</i>	16	4.6	22	5.3	1.9	7.0	5.6	35.2
<i>Ulmus rubra</i>	22	6.4	27	6.5	.73	2.6	5.2	19.7
<i>Fagus grandifolia</i>	12	3.5	22	5.3	1.5	5.5	4.8	35.5
<i>Acer saccharum</i>	25	7.4	20	4.8	.43	1.6	4.6	16.0
<i>Quercus rubra</i>	8.6	2.5	16	3.9	2.0	7.3	4.6	47.3
<i>Quercus shumardii</i>	5.0	1.5	9	2.2	2.2	8.0	3.9	72.7
<i>Fraxinus pennsylvanica</i>	13	3.8	16	3.9	.69	2.5	3.3	24.2
<i>Tilia americana</i>	13	3.8	15	3.6	.39	1.4	2.8	19.2
<i>Acer rubrum</i>	7.8	2.3	10	2.4	1.1	4.0	2.9	36.4
<i>Quercus muehlenbergii</i>	4.2	1.2	13	3.1	1.1	4.0	2.8	53.7
<i>Sassafras albidum</i>	11	3.3	13	3.1	.32	1.2	2.5	18.0
<i>Prunus serotina</i>	7.5	2.2	18	4.3	.23	.84	2.5	18.7
<i>Ulmus thomasi</i>	8.9	2.6	16	3.9	.14	.51	2.3	15.6
<i>Carya laciniosa</i>	3.9	1.1	12	2.9	.52	1.9	2.0	37.1
<i>Carya cordiformis</i>	5.6	1.6	10	2.4	.51	1.9	2.0	32.5
<i>Juglans nigra</i>	4.7	1.4	9	2.2	.42	1.5	1.7	35.0
<i>Quercus macrocarpa</i>	2.8	.82	5	1.2	.76	2.8	1.6	54.0
<i>Nyssa sylvatica</i>	3.9	1.1	7	1.7	.41	1.5	1.4	28.6
Others ¹	16.1	4.7	44	10.6	1.3	4.7	6.7	—
TOTALS	340 (138)		415		27.5 (120)			

¹Other species in descending order of percent importance are: *Quercus palustris*, *Carpinus caroliniana*, *Carya glabra*, *Celtis occidentalis*, *Acer negundo*, *Q. bicolor*, *Platanus occidentalis*, *Crataegus* spp., *Fraxinus nigra*, *Q. imbricaria*, *Cercis canadensis*, *Gleditsia triacanthos*.

TABLE 3. *Comparison of Dobbs Park old-growth to other Indiana stands on similar topography.*

	Dobbs Park	Bryan	Beckville	Meltzer
Number of Species -----	34	35	42	27
Species in common -----	—	28	25	24
Leading Dominants -----	Ua, Fa, Qa	Qa, Fa, Qr	Ar, Qr, Qa	Qsh, Fg, Fa
Coefficient of Similarity -----	—	52%	40%	43%
Basal Area -----	120	125 ¹	129	149
Density -----	138	80 ¹	104	122

¹Lower tree size limit of 5.0 inches dbh lowers values for density (substantially) and basal area (slightly) for Bryan Nature Preserve.

Most stems of these two species are in the 6-inch (15-cm) size class, and account for the increase in stem density.

Shifts in dominants lowers the coefficient of similarity to 40-52% (Table 3), but at least 24 species are common to these stands. Lowland depressional species predominate in all stands, with mesic and xeric species restricted to better-drained low ridges.

A size-class-log density plot (not included) for all species collectively very closely approximated a straight-line relationship, reflecting the excellent representation of all size classes and the general lack of disturbance.

Future work concerning the trends in changing species composition and elm replacement will be studied by revision of the large-scale map at decade intervals. An evaluation of tree distribution patterns is presently in progress.

Acknowledgments

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ENGINEERING

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ABSTRACTS

An Investigation of the Oxygen Sag Equation and a Modified Mathematical Explanation for Studying Stream Assimilative Capacity. ROBERT H. L. HOWE, West Lafayette, Indiana.—The dissolved oxygen sag equation deficit and its relation with time, pollution loads of both carbonaceous and nitrogenous components and reaeration development is modified and discussed in order to indicate the proper dissolved oxygen coordinate significance along the river or stream studied or surveyed, when plotted graphically or computed statistically.

A revised interpretation for determining the reaeration coefficient K_2 with respect to temperature changes is introduced. The meaning of the reaeration kinetics involving $(D)_R = D_0 e^{K_2 t}$ is emphasized, where D_0 is the dissolved oxygen deficit at time $t = 0$, and $(D)_R$ is the quantity of dissolved oxygen introduced into the water by reaeration due to stream flow.

The significance of the dissolved oxygen deficit is replaced by the term $C_s - C$, where C_s is the dissolved oxygen saturation concentration and C is the dissolved oxygen concentration measured. Thus, the dissolved oxygen deficit equation is expressed by all factors involved.

The critical time t_c can now be solved by either a first order expression or a second order derivation as desired.

Classical work on the subject is discussed, reviewed and compared.

Persistence in Daily Rainfall Occurrences in Indiana and Probabilities of Droughts. J. W. DELLEUR and M. L. KAVVAS, School of Civil Engineering, Purdue University, West Lafayette, Indiana 47907.—The long-term trends, the cyclicities, the covariance structure and the clustering of daily rainfalls are identified by the rate of occurrence function, the intensity function, the variance-time function and the spectrum of counts of daily rainfall and by the log-survivor function of the inter-arrival times. These statistics are used to calibrate a cluster model of daily rainfall occurrences from which the probabilities of drought can be obtained.

Thermal Load Allocations for Power Plants in the Lower Wabash River

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Abstract

This study reports the strategies of thermal load allocations for the five power plants in the lower Wabash River. A one dimensional river temperature prediction model was used to allocate thermal loads. Results indicate that for summer seven-day 1-in-10-year low flow, and also for seven-day 1-in-10-year low flow, the limiting condition was not the maximum monthly limiting temperature of the river, but the maximum temperature rise above ambient temperature. This is five degrees Fahrenheit (2.7°C) for the Wabash River as per Indiana Stream Pollution Control Board's SPC 1R-3. For the first power plant, the limiting condition was the upstream river water temperature.

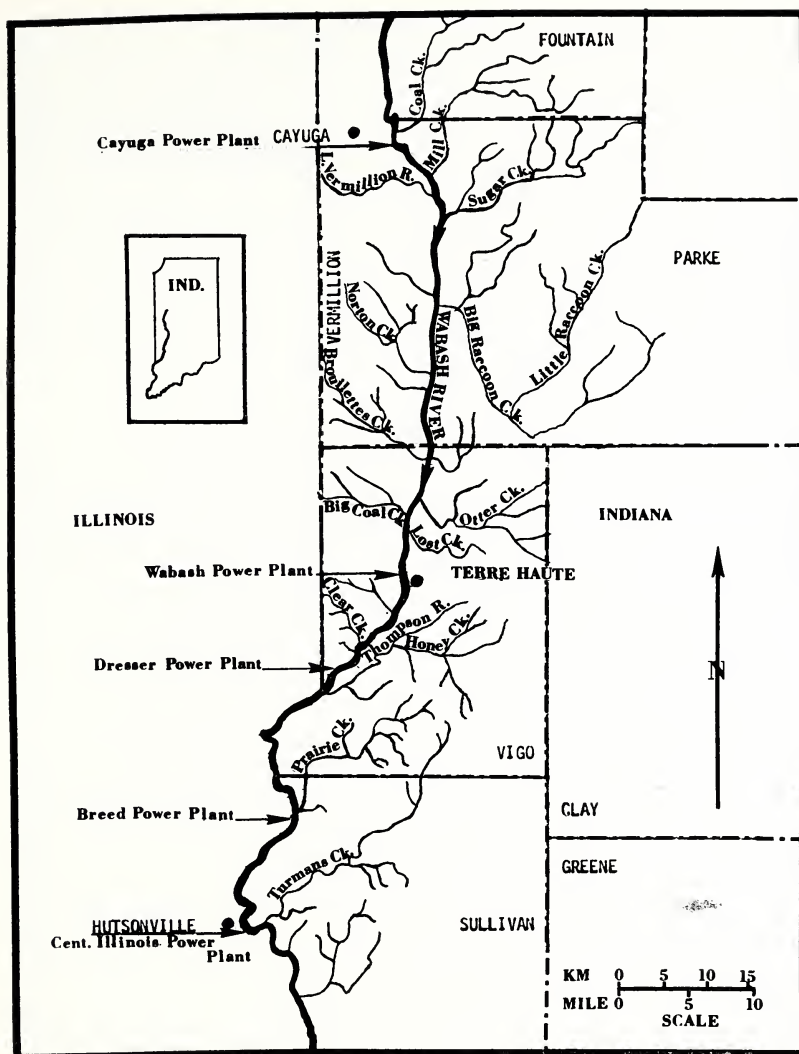
Introduction

The electric power industry requires cooling water in order to efficiently generate electricity. The water withdrawn by a power plant for once-through cooling systems circulates through the power plant condensers and absorbs most of the heat retained by the steam after it leaves the turbine and before the condensate is returned to the feedwater heaters and boilers. The quantity of water required for this purpose varies depending upon plant size, plant heat rate, and the acceptable temperature rise of the cooling water. Returning the now-heated water directly to the stream from which it was withdrawn may contribute to stream pollution.

The segment of the Wabash River considered for this study includes about 84 miles from Cayuga, Indiana, to near Hutsonville, Illinois (Figure 1). The purpose of this study is to estimate the allowable heat discharge for the following power plants located in this reach of the Wabash River: Cayuga Power Generating Station, Wabash Power Generating Station, Dresser Power Generating Station, Breed Power Generating Station, and Hutsonville Power Generating Station (Figure 1). After this study service from Dresser Power Generating Station was discontinued.

Biological Considerations

A reach of the Wabash River adjacent to the Wabash Generating Station was taken as the study area for the analysis of biological effects of the thermal discharge for said plant (3). A segment of the river approximately 3.5 km long, 122 m wide, and averaging less than 3 m deep (during summer low flows) was divided into ten subareas. Save for a shallow riffle area, the subareas were fairly homogeneous in depth, woody cover and bottom substrate. Although ten subareas were defined, they were combined into three thermal zones: Zone 1, a cool upstream section; Zone 2, a short, hot section near the power plant effluent which averaged $7-9^{\circ}\text{C}$ ($13-16^{\circ}\text{F}$) above ambient; and Zone 3, a long, varied (both temporally and spatially) thermal area

FIGURE 1. *Location Map*

downstream of the mixing zone which averaged 1-3°C (2-5°F) above ambient.

The study area for the Cayuga Generating Station was unique in the respect that it contained all of the various habitats (except backwater areas) found in the Wabash River. Ultimately, a 5.2 km segment was divided into eight subareas. Each subarea was nearly homogeneous concerning habitat type. The various habitats ranged from shallow, sandy bottoms with sluggish flows, through strongly

flowing water with mud banks and little cover, to gently flowing gravel-bottomed beds with woody bank cover.

A variety of capturing methods were used for fish, but it was found that electrofishing with pulsating D.C. current produced better results than hoop or ridged "D" nets. Providing an artificial substrate proved to be the most effective means for sampling macroinvertebrates.

The regularity of the behavioral responses was sufficient enough to justify the use of catch data for the Wabash Generating Station area to validate the establishment of optimum temperature ranges for species in the Cayuga area. As predicted, species that were expected to avoid the heated areas (including goldeye, redhorse, sauger, skip-jack herring and various centrarchids) did, while those that were expected to be attracted to the warmer segments (gar, carp, flathead catfish, and carpsuckers) were.

Strategies for Thermal Load Allocations

The strategy used in this report for allocating thermal loads for the five power plants in this reach of the Wabash River was based on meeting the water quality standard specified in the Indiana Stream Pollution Control Board's Regulation SPC 1R-3 (4). The SPC 1R-3 has three general types of water temperature criteria that must be met. These are: a) monthly maximum allowable temperatures which are 90°F in June through September; b) a maximum allowable temperature increase which is 5°F above a defined base temperature; and c) an allowable mixing zone at the edge of which, temperature criteria must be met.

Moreover, the thermal effluent limitations guidelines set forth as mandated by Public Law 92-500 dictates that all existing power plants must use "Best Practicable Control Technology currently Available" (BPT) to reduce thermal loads by no later than July 1, 1977. Also the existing power plants must use "Best Available Technology Economically Achievable" (BAT) to reduce thermal load by no later than July 1, 1983 (7). The above reference also gives the criteria for exemption to the thermal limits required by the best practicable control technology currently available or the best available technology economically achievable.

Alternative strategies to allocate thermal load for the power plants which will not violate SPC 1R-3 are given in appendix I.

Model Used

There are two fundamental approaches to the study for predicting heat loss in a flowing stream. One formulation of the heat dissipation is based on energy budget relationships and the other is the empirical approximation.

Ohio River Valley Water Sanitation Commission (ORSANCO) used their model STREAM (5) solely for Ohio River temperature prediction. In this model the temperature change is estimated based on the exponential die-away of the difference between the river temperature and the estimated normal temperature of the river.

Edinger-Geyer's(2) one dimensional model was used to predict temperatures along a river. The model basis is a heat budget which is used to determine an equilibrium temperature and a heat exchange coefficient. The model COLHEAT developed by Raphael (6) employs a heat budget to simulate the effect of the local environment on the rate of heat exchanged between the water body and the atmosphere. The analytical models of thermal discharges available for flowing streams may also be classified by regions affected by heated dischargers such as near field, far field, and broad thermal trends. This may also be classified based on type of discharge such as submerged discharges, surface discharges, etc. A review of the analytical modeling of thermal discharges is given by Benedict et. al (1).

The amount of data necessary to use any elaborate model for predicting river water temperature was not available for the present study, so a simple empirical model developed by LeBosquet (8) was used. This method of predicting heat loss in a flowing stream is based on the assumption that the rate of decrease of temperature differential between air and water, when the temperature of the air remains constant, is a constant proportion of the remaining temperature differential. This is expressed in mathematical form as follows:

$$-\frac{dT}{dt} = KT \quad (1)$$

Where

T = Temperature differential between air and water

K = Constant

t = Time

By integrating equation (1), expressing it in common logarithmic form and substituting $K = \frac{UA}{G}$ equation (2) is obtained

$$\log \frac{T_1}{T_0} = \frac{-(U \times 0.0102 \times W \times D)}{Q} \quad (2)$$

Where

T_1 = Temperature differential between water and air at any time t.
 T_0 = Initial temperature differential.

A = Surface area of stream, sft (Cm/929)

D = Distance along the river course, miles (Km/1.609)

W = Mean width of stream channel, ft (Cm/30.48)

G = Weight of water between two locations, lb (Kg/2.2)

Q = Runoff of the stream, cfs ($m^3/sec/0.0283$)

U = Coefficient of heat transfer, BTU/Hr. ($erg/sec/2.93 \times 10^6$)

If river water temperatures are observed at two locations D0 and D1, equation (2) may be written as equation (3)

$$U = \frac{0.0102 \times W \times D}{\log T_{D0} - \log T_{D1}} \quad (3)$$

Where

T_{D0} , T_{D1} = Temperature differential between water and air at locations D0 and D1, respectively, degrees Fahrenheit (Celsius/0.55)

The following data are required for the model to calculate the river water temperature downstream of a thermal effluent discharger and the upstream river water temperature of the next discharger in a stream system: number of reaches the stream system is divided into, average air temperature, mean width of stream channel for each reach, length of each reach, discharge of the stream in each reach, coefficient of heat transfer, total heat load of each thermal effluent discharger.

The data used for the determination of coefficient of heat transfer, U , were obtained by U.S. Environmental Protection Agency's Evansville office for a reach of 6.5 miles (10.46 km) below Cayuga Power Plant. The U value was estimated as 23.8 BTU/HR - sq. ft - $^{\circ}\text{F}$ (136.3 Joules/sec-m $_2$ - $^{\circ}\text{C}$). Figure 2 shows the plot of computed river water temperature and measured average river water temperature with distance on October 10, 1974. The data used are given in Table 1.

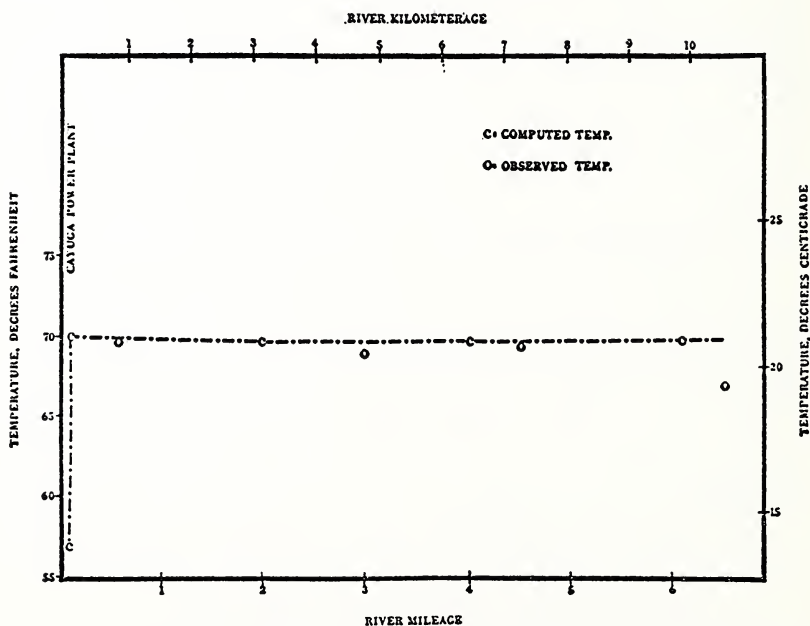


FIGURE 2. Computed and measured river water temperature downstream of Cayuga Power Plant

Results

The purpose of the model is to determine the allowable thermal loads which would not violate the SPC 1R-3 for summer seven-day 1-in-10-year low flow and seven-day 1-in-10-year low flow.

The data used for the low flow characteristics (seven-day 1-in-10-year and summer seven-day 1-in-10 year) of the Wabash River at the location of power plants were estimated by interpolating the low flow data at the USGS gauging stations at Covington, at Montezuma, at

Terre Haute, and at Riverton (Table 2). The river water temperature at Lafayette was used for estimating the intake water temperature of Cayuga Power Plant. The data used are shown in Table 3.

The estimated maximum heat load of the plants used for this study is shown in Table 4. For the present study, air temperature over the reach of the Wabash River considered was taken equal to the air temperature of Terre Haute. The data used is shown in Table 3.

TABLE 1. *Data used for verification of the model*

Tran.	Location	River Width ft (m)	Avg. Water temp. °F (°C)	Air temp., °F (°C)	River Flow, cfs (m ³ /sec)
1	300 ft (91m) upstream of Cayuga Power Plant intake	352 (107)	57.2 (14.0)	62 (16.7)	1921 (54.4)
2	50 ft (15m) downstream of heated water discharge	272 (83)	64.7 (18.2)	68 (20.0)	1921 (54.4)
3	2500 ft (16m) downstream of heated water discharge	389 (118)	69.6 (20.9)	68 (20.0)	1921 (54.4)
4	3 miles (4.8km) downstream of heated water discharge	469 (143)	69.4 (20.8)	70 (21.1)	1921 (54.4)
5	4.5 miles (7.2km) downstream of heated water discharge	308 (94)	69.6 (20.9)	70 (21.1)	1921 (54.4)
6	6.5 miles (10.5km) downstream of heated water discharge	434 (132)	66.8 (19.3)	62 (16.7)	1921 (54.4)

Thermal effluent discharge of the Power plant = 1248 cfs (35.3m³/sec)

U value used = 23.8 Btu/Hr-ft²°F (1.36×10^9 erg/sec-m²·°C)

Average air temperature = 66.7°F (19.3°C)

TABLE 2. *Low Flow of Wabash River*

Location	Drainage Area, Sq. Mile (sq. km)	Summer Seven Day 1 in 10 Yr. cfs (m ³ /sec)	Seven Day 1 in 10 Yr. cfs (m ³ /sec)
Wabash River at Covington	8,208 (21,258)	820 (23.2)	660 (18.7)
Wabash River at Cayuga Plant	10,006 (25,915)	920 (26.0)	753 (21.3)
Wabash River at Montezuma	11,100 (28,749)	980 (27.7)	810 (22.9)
Wabash River at Wabash River Power Plant	12,162 (31,499)	1,154 (32.6)	926 (26.2)
Wabash River at Terre Haute	12,200 (31,598)	1,160 (32.8)	930 (26.3)
Wabash River at Dresser Power Plant	12,423 (32,175)	1,249 (35.3)	972 (27.5)
Wabash River at Breed Power Plant	12,796 (33,141)	1,398 (39.6)	1,043 (29.5)
Wabash River at Hutsonville Power Plant	13,048 (33,794)	1,499 (42.4)	1,090 (30.8)
Wabash River at Riverton	13,100 (33,929)	1,520 (43.0)	1,100 (31.1)

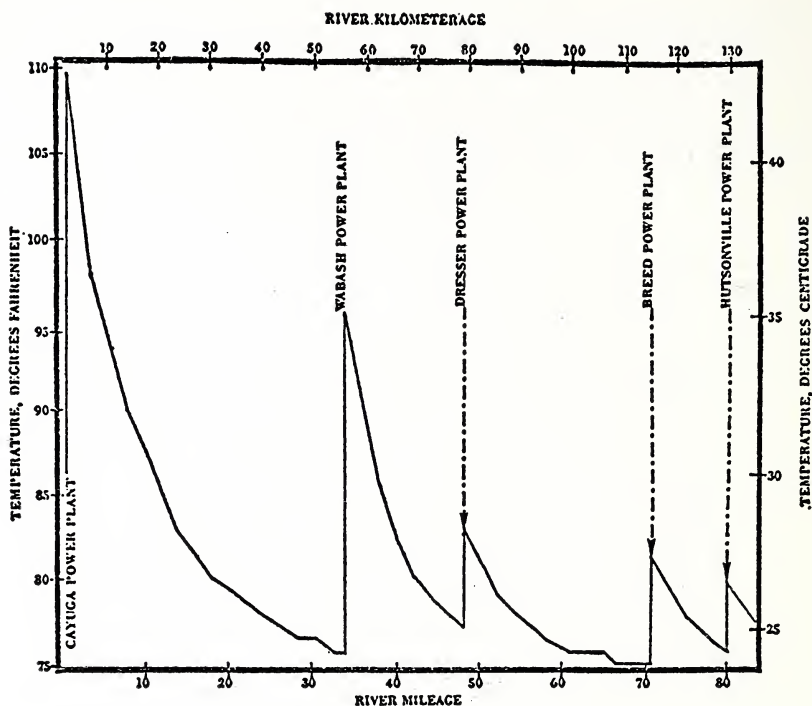


FIGURE 3. River water temperature with distance for summer seven day one in ten year low flow

The model was simulated for the seven-day, 1-in-10-year low flow and for the summer seven-day 1-in-10-year low flow. Figures 3 and 4 show the plot of river water temperature with distance for seven-day, 1-in-10 year low flow and for the summer seven-day, 1-in-10 year low flow respectively. The heat load used from the power plant is shown in Table 4.

Discussions and Conclusions

The computed river water temperature compares fairly well with the measured river water temperature (October 10, 1974), after mixing, except for the last transect as shown in Figure 2. This may be explained by the fact that for the model an average air temperature was used, whereas, in actual condition, there was a rapid drop of air temperature from 70°F (21.1°C) to 62°F (16.6°C) between transect 5 and transect 6.

It is obvious from Figure 3 that with summer seven-day, 1-in-10 year low flow and with maximum thermal loads for the power plants there would be violations of SPC 1R-3 below the first four power plants. It was found that if the heat loads for the first four power plants were reduced to meet the SPC 1R-3, the Indiana Stream Regulation would not be violated below Hutsonville Power Plant for the maximum

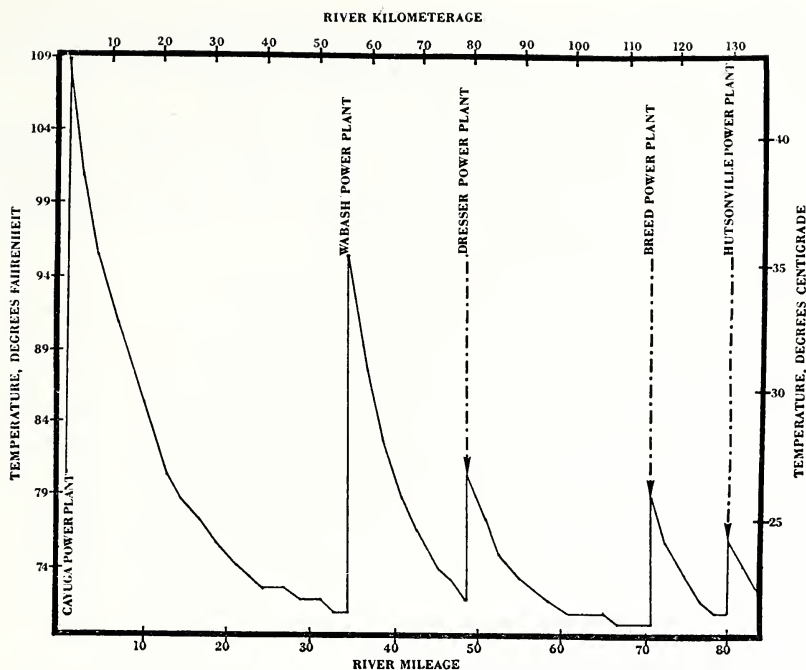


FIGURE 4. River water temperature with distance for seven day one in ten year low flow

heat load of that power plant. This is also true for seven-day 1-in-10-year low flow.

It was found that with the variation of coefficient of heat transfer, U , the amount of heat that the first four power plants would have to reduce did not vary. This is due to the fact that during summer seven-day, 1-in-10-year low flow the limiting condition is not the maximum monthly limiting temperature of the river, but the maximum temperature rise above ambient temperature which is 5°F (2.8°C) for the Wabash River. For the Cayuga Power Plant, the limiting condition is the upstream river water temperature. The maximum rise of river water temperature allowable for summer months is 90°F (32.2°C). Therefore, the amount of heat that could be discharged by the Cayuga Power Plant when the upstream river water is 86.9°F (30.5°C) should not increase the temperature downstream after mixing more than 3.1°F (1.7°C).

For the present study, the allowable heat loads that the five power plants could put into the Wabash River were based on seven-day 1-in-10-year low flow and summer seven-day 1-in-10-year low flow. There are a few questions that could be asked about the values used in the model for the thermal load allocations:

What river water temperature upstream of Cayuga Power Plant should be used: it may be average monthly water temperature for summer

months, summer seven-day 1-in-ten-year daily mean temperature or maximum daily mean temperature, or some other temperature? For this study no correction factor was applied for the change of river water temperature between Lafayette and Cayuga.

What air temperature over the river reaches should be used: it may be the maximum monthly temperature for summer months, the daily maximum air temperature for summer months, summer seven-day 1-in-10-year maximum daily mean temperature or any other air temperature?

TABLE 3. *Data used for thermal load allocations*

Summer 7 day in 10 year low flow :

	Cayuga Power Plant	Wabash River Power Plant	Dresser Power Plant	Breed Power Plant	Hutsonville Power Plant
Flow, cfs (m ³ /sec)	920 (26.0)	1154 (32.6)	1249 (35.3)	1398 (39.6)	1499 (42.4)
Thermal load from Power Plants, Btu/Hr (Joules/sec)	47.99x10 ⁸ (1.41x10 ⁹)	49.88x10 ⁸ (1.46x10 ⁹)	17.38x10 ⁸ (5.09x10 ⁸)	20.05x10 ⁸ (5.87x10 ⁸)	12.35x10 ⁸ (3.61x10 ⁸)
River water temperature above Cayuga Power Plant, °F (°C)	86.9 (30.5)				
Air temperature over the reaches, cf (°C)	75.6 (24.2)	75.6 (24.2)	75.6 (24.2)	75.6 (24.2)	75.6 (24.2)
Width of river, ft (m)	173 (52.7)	340 (103.6)	360 (109.7)	458 (139.6)	460 (140.2)
Coefficient of heat transfer, Btu/Hr-ft ² °F (erg/sec-m ² -°C)	23.8 (1.36x10 ⁹)	23.8 (1.36x10 ⁹)	23.8 (1.36x10 ⁹)	23.8 (1.36x10 ⁹)	23.8 (1.36x10 ⁹)

7 day 1 in 10 year low flow :

	Cayuga Power Plant	Wabash River Power Plant	Dresser Power Plant	Breed Power Plant	Hutsonville Power Plant
Flow, cfs (m ³ /sec)	753 (21.3)	926 (26.2)	972 (27.5)	1043 (29.5)	1090 (30.8)
Thermal load from Power Plants, Btu/Hr (Joules/sec)	47.99x10 ⁸ (1.41x10 ⁹)	19.88x10 ⁸ (1.46x10 ⁹)	17.38x10 ⁸ (5.07x10 ⁸)	20.05x10 ⁸ (5.87x10 ⁸)	12.35x10 ⁸ (3.61x10 ⁸)
River water temperature above Cayuga Plant, °F (°C)	80.6 (27)				
Air temperature over the reaches, °F (°C)	70.5 (21.4)	70.5 (21.4)	70.5 (21.4)	70.5 (21.4)	70.5 (21.4)
Width of river, ft (m)	145 (44.2)	290 (88.4)	300 (91.4)	445 (135.6)	450 (137.2)
Coefficient of heat transfer, Btu/Hr-ft ² °F (erg/sec-m ² -°C)	23.8 (1.36x10 ⁹)	23.8 (1.36x10 ⁹)	23.8 (1.36x10 ⁹)	23.8 (1.36x10 ⁹)	23.8 (1.36x10 ⁹)

TABLE 4. *Maximum heat load of the power plants*

Plant Name	Name Plate Capacity MW	Total Heat to cooling, Btu/Hr (Joules/sec)
Cayuga Power Plant	1011	$47.99 \times 10^8 (1.41 \times 10^9)$
Wabash River Power Plant	970.25	$49.88 \times 10^8 (1.46 \times 10^9)$
Dresser Power Plant	221	$17.38 \times 10^8 (5.09 \times 10^8)$
Breed Power Plant	450	$20.05 \times 10^8 (5.87 \times 10^8)$
Hutsonville Power Plant	215	$12.35 \times 10^8 (3.61 \times 10^8)$

What thermal loads should be used for the power plants: all power plants may discharge maximum thermal loads, or one plant is at maximum and the rest of the plants may discharge average thermal loads?

At present, there is no guideline available for the above variables. The following conclusions may be drawn from this study:

- 1) For summer seven-day 1-in-10-year low flow and also for seven-day 1-in-10-year low flow with maximum thermal loads for the power plants there would be violations of SPC 1R-3 below the first four power plants.
- 2) For the above low flow conditions, the limiting condition is not the maximum monthly limiting temperature of the river, but the maximum temperature rise above ambient temperature which is 5°F (2.7°C) for the Wabash River.

Acknowledgment

The authors wish to express appreciation to Mr. Samuel L. Moore and Dr. T. P. Chang for their support and encouragement in the preparation of this paper.

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Appendix I

In order to take advantage of seasonal changes in river flow and water temperature so that during periods of high flow and low water temperature additional amounts of thermal load could be discharged, the following scheme may be adopted to satisfy the SPC 1R-3:

$$\frac{Q_{UP} \cdot T_{UP} + Q_{EF} \cdot T_{EF}}{Q_{UP} + Q_{EF}} = T_{ALL} \leq \begin{array}{l} \text{Monthly maximum river water} \\ \text{temperature allowed under} \\ \text{SPC 1R-3} \end{array} \quad (A1)$$

$$T_{ALL} - T_{UP} = 5^{\circ}\text{F} \quad (2.78^{\circ}\text{C}) \quad (A2)$$

Where

Q_{UP} = Upstream river discharge.

T_{UP} = Upstream river water temperature.

Q_{EF} = Effluent flow from the power plant.

T_{EF} = Effluent temperature.

By knowing the upstream river discharge and temperature, the effluent flow and temperature of the plant may be regulated so that downstream temperature, T_{ALL} , after mixing satisfies equations A1 and A2. Another alternative would be to monitor upstream and downstream river water temperatures, T_{UP} and T_{ALL} respectively. The effluent flow and temperature may be adjusted so that T_{ALL} and $T_{ALL} - T_{UP}$ meet the SPC 1R-3.

Indiana "National Pollutant Discharge Elimination System" Tracking System

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Abstract

The massive and complex water pollution control programs currently underway have created an acute need for the use of computerized data management systems. This paper summarizes the development of a computerized tracking system which is designed to assist Indiana in managing its National Pollutant Discharge Elimination System (NPDES). In addition to a short history of the development, the structures of inputs, system design and outputs of the NPDES tracking system will be presented. The paper is concluded by a discussion of the types of problems Indiana has encountered during the processes of system design and program implementation.

Introduction

At the beginning of 1975, the U.S. Environmental Protection Agency (USEPA) granted permanent authority to the Indiana Stream Pollution Control Board (ISPCB) to administer the NPDES permit program for Indiana in accordance with 1972 amendments to the Federal Water Pollution Control Act. The ISPCB now has the responsibility of issuing discharger permits, monitoring effluent conditions and enacting enforcement programs.

The first step of the NPDES program involves a waste load allocation for each permittee to determine effluent limitations and a schedule of compliance (Figure 1). After receiving certification, each permittee submits a monthly report stating the self-monitoring results of effluent testing and progress with the compliance schedule. At the same time, ISPCB, in cooperation with the USEPA, will conduct compliance monitoring in order to check and verify the permittee's self-monitoring records. This monitoring also provides stream and effluent data to evaluate the effectiveness of the pollution abatement program. Once a violation is identified, either by self-monitoring or by compliance monitoring, enforcement action will be taken in order to correct the non-compliance conditions. At the end of a permit cycle, usually five years, ISPCB will re-evaluate the status of stream water quality, the progress of wastewater treatment technology, and will then re-evaluate permit conditions.

This paper describes Indiana's current efforts to establish a computerized NPDES tracking system that will handle its data base manipulation, violation identification as well as enforcement programs. A major portion of this system has been operational while others are still in the design stage. The Computer used for implementing this system is an IBM 370/165, model 2, which is accessed through an IBM 2780 terminal.

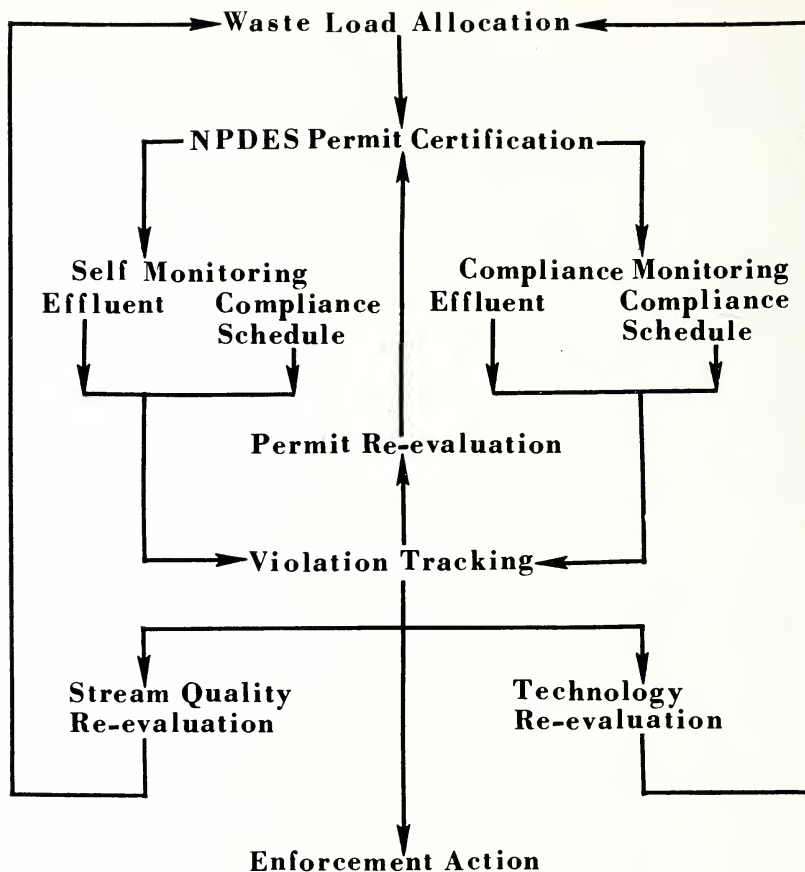


FIGURE 1. NPDES Permit Flow Diagram

A Short History

Between 1973 and 1974, the USEPA headquarters attempted to build an automated data tracking system named General Point Source File (GPSF) with remote data entry and retrieval through low speed terminals in USEPA regional offices and state environmental agencies. The plan consisted of a series of subsystems which handle NPDES permit application, post-issuance compliance as well as enforcement logs. By the end of 1974, the design of GPSF was discontinued because of both technical and economical difficulties. Instead, a much reduced-scale system named Permit Compliance System (PCS) was designed(3). The PCS provides forecasting capabilities for compliance schedules but does not handle effluent data. Furthermore, the PCS is intended for USEPA internal use only.

The design of Indiana computerized NPDES tracking system was commenced in the spring of 1974 as one component of the Indiana Water Pollution Control Information System(1). Its objectives are:

1. To provide a means to store and to retrieve compliance schedule data, effluent parametric data as well as compliance monitoring data.
2. To analyze the input data and to identify violations for self-monitoring report, both in effluent limitations and in compliance schedule.
3. To generate notice of violation monthly for dischargers and to prepare violation summary reports for USEPA quarterly.
4. To provide forecasting capabilities for compliance scheduling activities and dates for permit expirations.
5. To keep track of the enforcement action activities.

At the end of October, 1975, the major portion of the system had been completed and the first four objectives mainly achieved. The enforcement phase, item No. 5, will be operational by the spring of 1976. Due to the computer hardware limitations in ISPCB, the current system is operated in batch mode. Future plans will include the on line capability when ISPCB computer system is updated.

Another system named GPLAN(2) has been designed by Purdue University which emphasizes query and retrieval services related to water quality planning activities. The GPLAN also incorporates a portion of the effluent violation analysis similar to the ISPCB system.

System Input

Presently ISPCB handles nineteen hundred permits which include dischargers from industrial, municipal and other types of wastewater treatment plants. Data input for those dischargers has been the most expensive task in the total NPDES tracking processes. Current input data include three major files, i.e., permit conditions, monthly self-monitoring data and compliance monitoring data. Each file contains effluent parametric figures and dates for compliance scheduling. In addition, an independent permittee identification file has been generated. The above-mentioned four files can be interfaced through their common code, i.e., the NPDES permit number. Future plans for system input will add data for enforcement history.

The permit identification file contains information relative to the type of the discharger, its office address, permit number, facility location, county and segment codes, name of receiving stream, permit expiration dates and permit status, such as permit in modification or permit in adjudicatory hearing. Some of this information is stored in header records which are included with each permittee's condition file. The permit condition file comprises the effluent and scheduling requirements specified in the permit. The effluent limitations consist of interim and final discharge rate, pollutant concentration, sample type, sample frequency, etc. The scheduling data consists of dates for completing various phases of planning, design and construction tasks. The above described information is compiled and stored in cards as soon as the permit is issued and requires constant updating because new permit issuance and modifications take place almost every month.

The self-monitoring reports of effluent measurements are submitted to the ISPCB monthly, allowing twenty eight days for laboratory analyses. The ISPCB requires the recording of individual sampling values as well as a monthly summary. Notification of a compliance schedule action is to be submitted within fourteen days after the due date. The summary is to indicate the maximum, average and minimum values of each effluent parameter, as well as the sample type and sample frequency. Because of the current limitation on keypunch resources, present practice is to store and to use summary data only. Future plan will use the individual sample values rather than monthly summary values.

Presently, the compliance monitoring survey is mainly confined to the two hundred seventeen major dischargers in Indiana. Each survey will include the measurement of the effluent discharge rate and quality specified in the permit, and sometimes the samplings of stream water both upstream and downstream of the outfall. Each survey also reports the progress of the construction schedules.

Future plans will include the storage of the information relative to enforcement activities, such as ISPCB orders, court orders and so on.

System Design and Structure

The present tracking system is designed for batch-mode operation. The input data is verified through pre-editing and updating routines and when ready, stored on disk and/or tape. Selection of appropriate data sets is done by computer control language as various programs are executed. The various files are manipulated by sorting and merging routines to create a data set structured for efficient analysis. Once this file has been created it is pre-examined by computer routines that further simplify it. This produces an idealized data stream for the complex violation analysis. Once the analysis has been made the violation results may be output to the various types of computer output media available.

Pre-Editing Subsystem

The data pre-editing subsystem has proven to be essential to the successful operation of the tracking system. Because of the public and legal significance of the citing of permit violations it is essential that the data used be as free from human error as possible. Identification numbers and various other codes must be checked for validity. Invalid items must be found and removed by updating procedures. A simplified flow chart of this system may be found in Figure 2. Various checks are made to eliminate errors from such things as duplicate reporting, amended reports, or improper identification codes. Once this is done the data is ready for violation analysis.

Self-Monitoring Violation Analysis

The analysis of self-monitoring reported data is an intricate process beginning with the determination of whether or not a report has been received. Even if no data are found in the file, special circumstances, such as permit under adjudication or modification, must be checked before a violation can be cited. If a report is received then

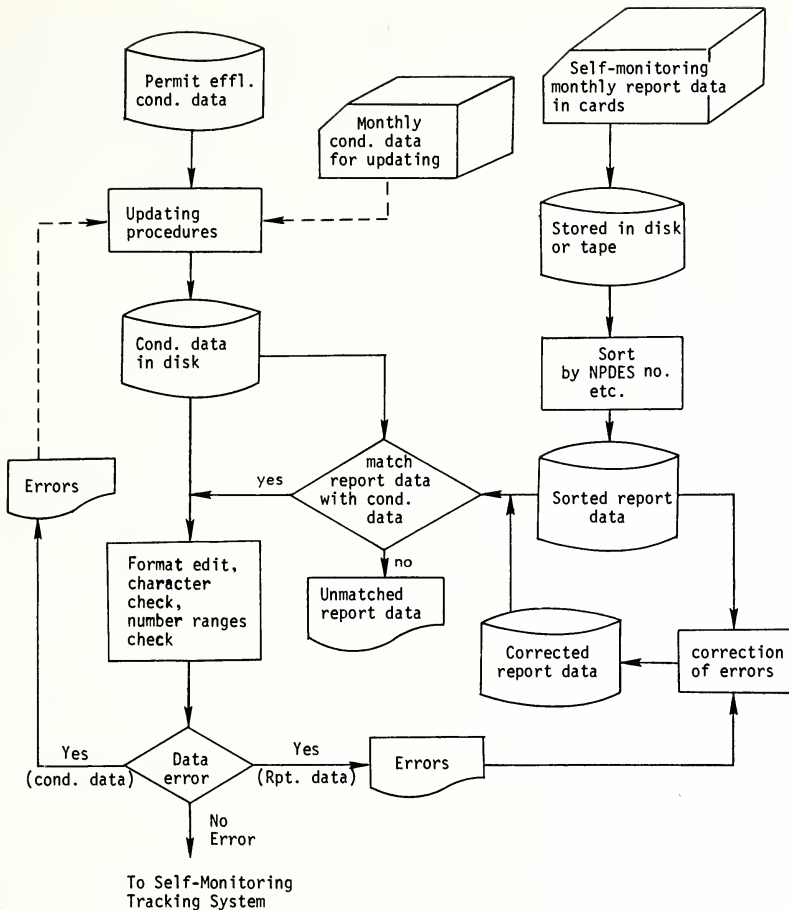


FIGURE 2. Data Pre-editing Program Flow Chart

each parameter enumerated in the permit must be examined. If zero effluent is indicated for a given outfall, the testing will proceed to the next outfall number in the data stream.

If an effluent discharge is indicated a check is first made to determine whether a given parameter is missing. Excuses such as permit modification or adjudication for that parameter, or measurement equipment problems, are also considered. The last step is to check violations due to effluent limitation exceedences, failure to comply with sampling frequencies or sampling methods. Figure 3 is a simplified flow chart of violation analysis.

Compliance Schedule Tracking Subsystem

The requirements of the compliance schedules are that a specific action be taken and notification be mailed to the Indiana Stream Pol-

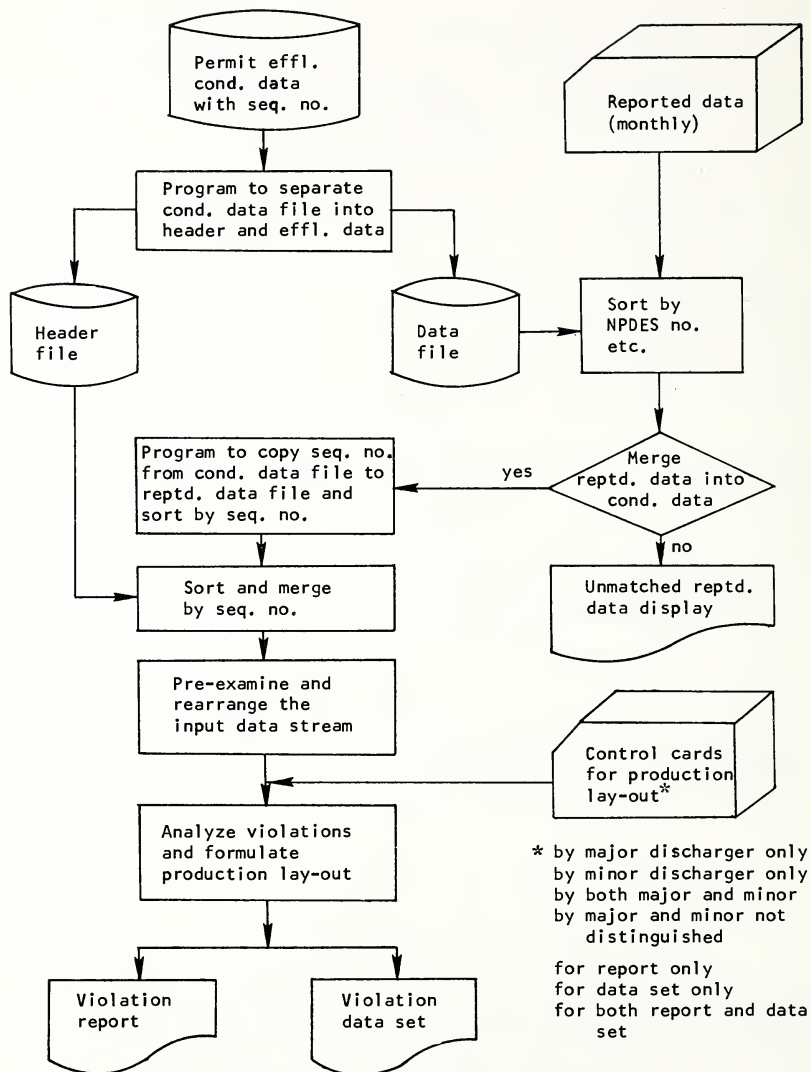


FIGURE 3. Self-Monitoring Violation Program Flow Chart

lution Control Board by a certain date. Four types of violations are possible. They are no action reported, action reported but not completed by schedule date, no notification received, notification received but late.

An inventory program assists in monitoring the progress of the permittees' actions. A register is generated listing schedules, reports received, and permit status. Also included with this inventory is a forecast of due dates. This aids in the determination of actions currently due or due in the near future.

NOV Generation Subsystem

Violation data from the self-monitoring report analysis and the compliance schedule tracking subsystem are merged and matched with appropriate address information from the identification files. These re-organized data are then entered into the Notice of Violation (NOV) generation subsystem which transforms all violation information, such as time, location, violation items into a formal letter form.

System Output

There are two basic types of output produced. One type is the "in-house" reports which are generated for violations and associated information and distributed to concerned departments. A second type is the "outgoing" reports or notices.

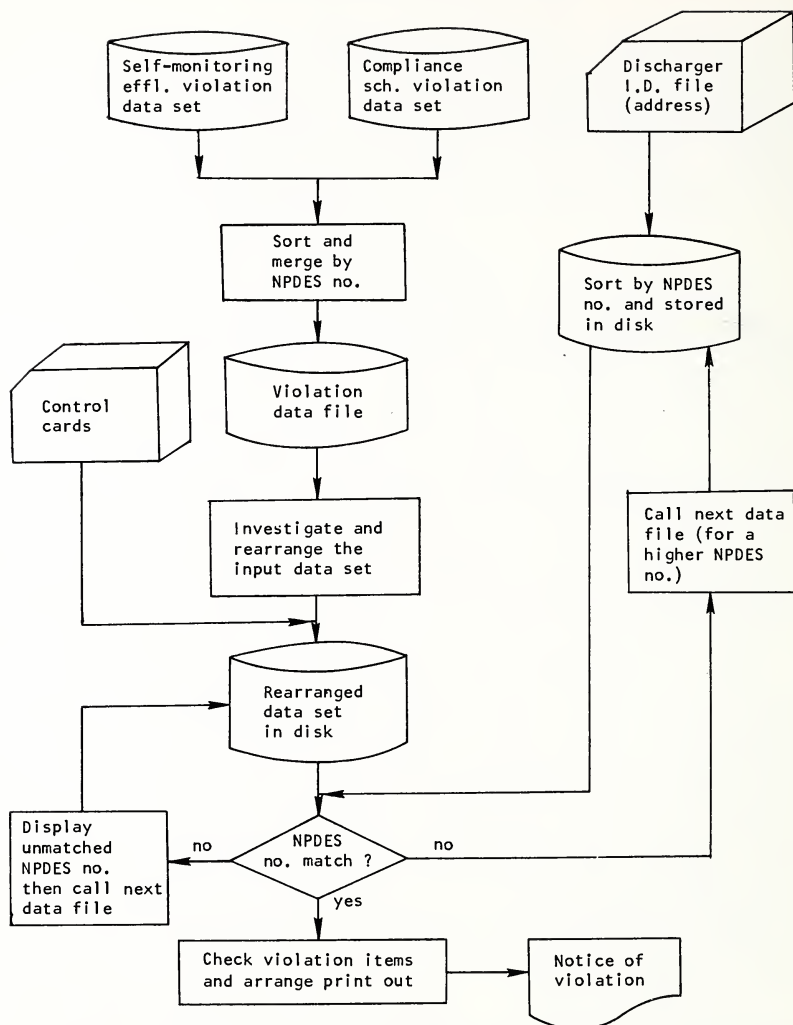
Currently there are five major "in-house" reports. One report represents a current inventory of dischargers requiring construction (compliance schedule), indicates dates which reports or actions are due, and forecasts items which are currently due or soon to be due. Another report presents monthly violations of these construction schedules. This includes items such as lateness, or failure to meet requirements and statistical summaries. Monthly reports are generated for effluent self-monitoring violations which indicate permit limits that were exceeded, improper sampling, or items missing in the data received.

This report includes many factors besides just data comparison. It indicates adjudication of items, permit modifications, major-minor status, current status of the discharge, and other special information. It is desirable to know well in advance which permits are approaching expiration in order to prepare for reevaluation and applications for new permits. A forecasting report is produced that can generate in advance a list of the dischargers that have permits expiring on or before a given month (generally 9 months in advance). A fifth type of "in-house" report is the report of data gathered by the monitoring surveys. This report shows the results of a survey, as they compare to permit requirements, and self-monitoring report data. A sixth type is in the planning stage. It will present an annual report from the self-monitoring data base.

There are two current "outgoing" outputs. The first of these are the violation letters generated by the computer and sent to violating dischargers as official notice that permit requirements are not being met. The volume on this may be as high as one thousand letters per month. A second outgoing output is generated quarterly and informs the Environmental Protection Agency of notices sent, and enforcement actions taken.

Operational Problems

Within the experience of the Indiana Stream Pollution Control Board, the most difficult and time consuming step in its NPDES tracking program is the establishment and maintenance of a reliable data base. This includes the permit condition file, self-monitoring file and compliance monitoring file. When at its full load, the Indiana Stream

FIGURE 4. *The Notice of Violation Flow Chart*

Pollution Control Board will receive each month nearly a quarter million pieces of facility, time schedule, effluent sampling and stream sampling data. For each piece of data, coding, keypunching, verifying and editing procedures are necessary in order to assure proper entry into the data base.

Due to the dynamic nature of the current stage of the NPDES program, the required constant updating of the tracking system presents another operational difficulty. New rules and new elements of data are added monthly, which causes instabilities in the input format and in the program structure itself.

In order to maintain an effective and timely enforcement program, the meeting of the closely scheduled deadlines for each processing step is very critical. Current scheduling allows only two weeks of processing time each month between the deadline for monthly report submission and the printing of the Notice of Violation. To maintain a smooth and reliable production line such as this requires scheduling, planning and dedication especially when one has to compete with other ISPCB projects for the use of computer time and keypunch services.

Although a vast majority of the violation decisions are made by the predetermined rules which have been programmed in the system, it should be noted that administrative judgment still plays a certain role in the decision step. Deviations such as misinterpretations, mailing delays and other excuses due to circumstantial evidences have happened every month which are found difficult to be incorporated in the computer program and therefore complicate the operational problems.

Discussions and Conclusions

The task of computerization of the NPDES tracking program for Indiana's nineteen hundred permits has been a challenging endeavor. The complex nature of the task is not only the result of the need to administer vast volumes of scheduling and effluent data, but results from the dynamic and complicated character of the process itself. Due to limited manpower availability in the ISPCB, and the pressing turn-around time required monthly in identifying violations and in sending notices to the violators, the computerized tracking system has become, in the past year, the key to successful enactment of the ISPCB's NPDES program.

In addition to the enforcement activity logging system, which is expected to be completed by next spring, the possible extension of the NPDES tracking system may include the incorporation of stream simulation models, for both conservative and non-conservative parameters. This extension will allow the system to handle such a permit that its effluent limitations are dependent on the stream flow, stream quality condition and seasonal factors. Secondly, this extension will facilitate the execution of future permit renewal program. The other possible extension is to tie the NPDES tracking system with GPLAN (2), which is capable of simulating stream quality parameters.

We have stated previously that the most expensive step is the establishment and maintenance of the data base. At this point, one should realize that the computerized effluent and stream sampling data base is not designed and used for short enforcement purposes only, it is also designed for the long-term goal, that is, to provide historical information in order to answer the future planning questions such as the impact of the permit program on water pollution control.

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Time Distribution of Short Time Increment Rainfall for Engineering Design

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Abstract

The knowledge of the time distribution of short time increment rainfall is of vital importance in solving certain hydrologic problems, such as the design of urban storm sewer systems. One of the important characteristics of temporal distribution of rainfall used in hydrologic design is the average percentage mass curve of rainfall. Huff has proposed a method of generation of rainfall hyetographs based on the average percentage mass curves of rainfall data.

In the present study we have used Huff's method to investigate the time distribution of ten minute and hourly rainfall data from West Lafayette, Indiana. The historical storms were classified into four groups depending on the occurrence of peak rainfall in the first, second, third or fourth quartiles of the storm period. The time distribution of rainfall in each quartile was expressed as cumulative percentages of storm depth and storm duration in terms of probability levels. The time distribution graphs derived from West Lafayette data were compared with those obtained by Huff for the rainfall data from east-central Illinois and discussed. Histograms were developed for the different quartile storms and an example is presented to illustrate the method of generating the hyetograph for a given storm.

Introduction and Statement of Objectives

The short time increment rainfall depth values corresponding to given frequencies and durations are often used in the design of urban storm sewer systems. Although, total storm depth and duration for a given location can be obtained or approximated easily, the information about temporal distribution of a given storm of a particular duration is not easily available. Stochastic models such as the urn model of Grace and Eagleson (1) can be used for the determination of the time distribution or the hyetograph of a given storm. However, these methods require rather advanced knowledge of probability theory, the use of a digital computer and the correlation structure of rainfall. These methods are also of use mainly for large scale data generation. In practice, there are occasions when the engineer is interested in generating a few hyetographs of a design storm. In such circumstances, a simpler procedure is of greater utility. The method proposed by Huff (2) is one such procedure.

The primary objective of the present study is to demonstrate the use of "average percentage mass curve" for the generation of hyetographs. The concept of "percentage mass curve" is well known and an extension of the above concept is the average percentage mass curves developed by Huff (2) for different probability levels. The method is quite simple and the computations can be carried out on a desk calculator. The second objective is to compare the results obtained by Huff with those of the present study and to draw conclusions regarding the variability in time distribution characteristics of short time increment rainfall at different locations and different samples.

Data Used in the Study

The results presented herein were obtained by the analysis of two different sets of data collected from rainfall stations in West Lafayette, Indiana. The first set of data consists of ten-minute rainfall values measured from 1970 to 1972 by a raingage located in the Ross Ade Upper watershed at the Purdue campus. The second set of data is the hourly rainfall values measured at the Purdue Agronomy Farm from 1969 to 1973. The location of these two rainfall stations is shown in Figure 1. Rainfall measured only during the months April to October were used in the analysis.

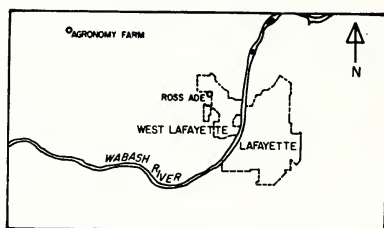


FIGURE 1. Location of Stations

The observed 10-minute and hourly rainfall values were separated into storms using the *critical lag* criterion of Grace and Eagleson (1). The critical lag τ_L was found to be 100 minutes for the 10-minute data and 15 hours for the hourly data by Rao and Chenchayya (3). The observed rainfall pulses were sequentially considered and when a period without rainfall of duration τ_L or greater appeared between two nonzero pulses, a new storm is said to commence. Thus, a *storm* is defined as a group of rainfall pulses preceded and followed by zero amplitude pulses of duration equal to or greater than the critical lag. The *storm interior* is the term used for the sequence of both zero and nonzero amplitude rainfall pulses of a storm and the sum of the magnitudes of the nonzero rainfall pulses of a storm is called the *storm depth*. In the present analysis, we have used only the storms with durations greater than 40 minutes for the ten-minute data and 4 hours for the hourly data. There were 174 and 133 storms respectively from the ten-minute and hourly rainfall data. The above storms and the storm interior values were used for investigating the time duration characteristics of rainfall at West Lafayette, Indiana.

Time Distribution Characteristics

The time distribution characteristics of rainfall were investigated by using Huff's method (2). In this method the historical storms are initially classified into four groups depending on the occurrence of peak rainfall in the first, second, third or fourth quarter of the storm period. The time-distribution of rainfall in each quartile is expressed as cumulative percentages of storm depth and storm duration in terms of probability levels from 10% to 90%. The probability

levels are adopted because of significant variability in the time-distribution of rainfall from storm to storm. This classification of storms can be easily seen to be an extension of the percentage mass curve concept. However, the above method can be used much more easily than the other methods, such as those based on urn models for determining the internal distribution of rainfall given total storm depth and duration. The results obtained from the above method for the rainfall data from West Lafayette are discussed below.

The number and the percentage frequency of the quartile storms of the observed data are presented in Table 1. These results show that the maximum number of storms are of the first quartile category and the minimum number are in the third quartile category. The corresponding percentage mass curves are presented in Figure 2. The percentage mass curves at different probability levels for both the ten-minute as well as hourly data show the same general trends. The percentage mass curves shown in Figure 2 were compared with those prepared by Huff (2) for 30-minute rainfall data from east-central Illinois. A typical comparison between the percentage mass curves of the first quartile storms of hourly data from West Lafayette and those from Huff's data is shown in Figure 3. Obviously there is

Quartile	Ten Minute Data		Hourly Data	
	Number	Frequency (%)	Number	Frequency (%)
First	57	32.8	64	48.1
Second	56	32.2	31	23.3
Third	27	15.5	9	6.8
Fourth	34	19.5	29	21.8
Total	174	100.0	133	100.0

TABLE 1. *Percentage Frequency of Quartile Storms*

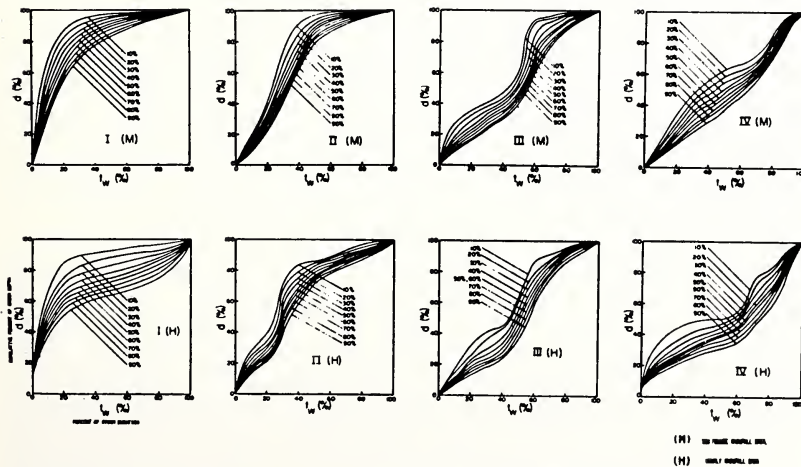


FIGURE 2. *Percentage Mass Curves Derived by Using Huff's Method*

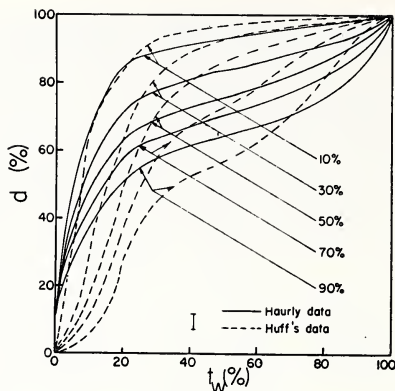


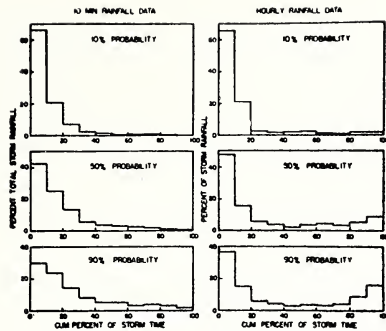
FIGURE 3. Comparison of Average Percentage Mass Curves (I Quartile Storms)

considerable difference between the percentage mass curves at the same probability levels. The comparative study of the percentage mass curves for the other quartile storms also showed similar differences. Although the above rainfall stations are located in similar climatic regions, the pronounced differences in the time distribution characteristics of rainfall may be attributed to the factors such as synoptic storm types, areal distribution, length and time step of the rainfall data considered in the analysis. For example, Huff used average rainfall data from a network of 49 recording gages distributed over an area of 400 square miles (1042 square kilometers) in east-central Illinois. The period of record was about 20 years. On the other hand, the data used in the present study were obtained from single rain gage measurements and the total period of the record is 5 years. Several other reasons similar to those discussed above can be cited for the obvious differences between the average percentage mass curves.

Generation of Hyetographs

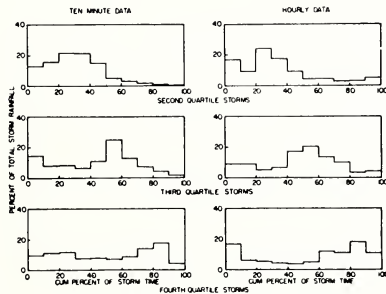
By knowing the storm depths and durations (such as those corresponding to a n year frequency) the hyetographs may be generated by the Huff's method. These are average hyetographs and an example of the computations is also given below. Presently we will consider only the characteristics of the hyetographs which may be obtained by Huff's method.

The histograms for the 10%, 50% and 90% probability levels for the first quartile storms are shown in Figure 4. The peak rainfall, by definition, occurs in the first quarter of the storm period at all probability levels. The intensity of rainfall exhibits an approximately exponential decrease with increasing storm duration. For example, the 50% probability histogram (Figure 4) indicates that in the first quartile storms of the ten-minute data, about 42% of the rainfall occurs in the first 10% of the storm period and about 90% of rainfall occurs in the first half of the storm period in 50% of the cases. The first quartile storms of hourly data shows that at 50% probability level,

FIGURE 4. *Selected Histograms of First Quartile Storms*

about 48% of rainfall occurs in the first 10% of the storm period and about 75% of rainfall occurs in first half of the storm period.

The histograms of the second, third and fourth quartile storms at 50% probability level are presented in Figure 5 for the ten-minute as well as hourly data. A comparison between the histograms of 50% probability level of the first, second, third and fourth quartile storms (Figures 4 and 5) for the ten-minute data indicate that the magnitude of the peaks are decreasing from the first quartile to fourth quartile storms. The same variation is also observed from the histograms of 50% probability level of hourly data.

FIGURE 5. *Histograms at 50% Probability Level*

Example

Let us assume that we want to generate the hyetograph for a IV quartile storm of 14 hours duration and 1.5 inches (3.8 cm.) depth. The average hyetograph of the IV quartile storm at 50% probability level is shown in Figure 5 in terms of percent of total storm depth and storm duration. The hyetograph of the generated storm computed from Figure 5 at 50% probability level is shown in Figure 6. The hyetographs of the storm at other probability levels (for example 10% and 90%) may be obtained from Figure 2.

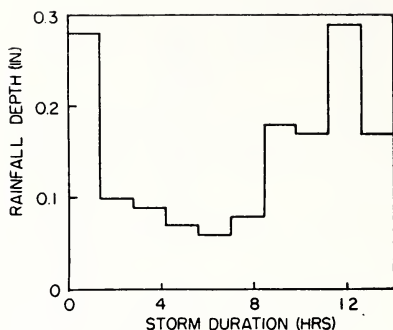


FIGURE 6. *Hyetograph of The Hypothetical Storm At 50% Probability Level*

If the rainfall peak within the storm is of concern in the design, the above procedure may be used to generate a first quartile storm, which would give a higher peak rainfall. Thus, the method is more flexible and can be used to generate hyetographs for all the quartile storms. If the probability of occurrence of the storm is known, the quartile category can be assigned in a probabilistic sense using the percentage frequencies of the quartile storms presented in Table 1. Further details may be found in Rao and Chenchayya (3).

Conclusions

The following conclusions can be presented from the foregoing analysis.

- (1) The time distribution characteristics of short time increment rainfall from West Lafayette, Indiana, could be represented by the average percentage mass curves at different probability levels.
- (2) In the West Lafayette area, first quartile storms occurred most frequently and third quartile storms most infrequently.
- (3) The comparison of time distribution characteristics between rainfall data from West Lafayette and those of east-central Illinois reveals that although the rainfall stations are located in similar climatic regions, the time distribution of rainfall can be significantly different. However, the variability which may be attributed to sampling variations and to spatial effects need further study.
- (4) The histograms developed from the percentage mass curves are quite useful to generate the hyetograph of a given storm.

Acknowledgements

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ENTOMOLOGY

Chairman: ROBERT W. MEYER, Department of Entomology
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VIRGIL R. KNAPP, Indiana Department of Natural Resources
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was elected Chairman for 1976

ABSTRACTS

A Modified Malaise: Description and Potential of an Adaptable Flying-Insect Controlling Device. RANDALL A. HIGGINS and T. L. HARRIS,¹ Department of Entomology, Purdue University, West Lafayette, Indiana 47907.—Operation of a non-attractive Malaise trap is dependent upon flying insects attempting to fly over a barrier, being funneled upward, and terminating with capture within a collecting device. This modified Malaise trap is composed of four nylon screen walls, an upward sloping awning, and a directional collecting device. The adaptable and self-contained trap has been tested in aquatic, aerial, and terrestrial habitats. The portability of this trap and its ability to sample flying insects from four directions independently and simultaneously are preferred attributes for various sampling situations.

Destruction of Cantaloupe Seedlings by Cucumber Beetles. J. A. BURNSIDE and B. D. BARRY, Midwest Deciduous Fruit Insects Laboratory, Agricultural Research Service, U. S. Department of Agriculture, Vincennes, Indiana 47591.—Cantaloupe seedlings 3, 6, 9, and 12 days old were infested with 0, 1, 2, 3, and 4 striped cucumber beetles, *Acalymma vittata* (F.), or spotted cucumber beetles, *Diabrotica undecimpunctata howardi* Barber. In general, the younger the seedling and the higher the population of insects, the more quickly the seedling was destroyed. The striped beetles were more destructive than the spotted beetles to 3- and 6-day-old seedlings. The opposite was true of 12-day-old seedlings, though the striped beetles ate more foliage, because the spotted beetles fed more on the stems. The average time required to destroy a 12-day-old seedling ranged from 6.1 to 10.8 days for the spotted cucumber beetle and was 15.6 days for the striped cucumber beetle.

Investigations of Propolis. RICHARD J. JUDY, JR., and TODD L. HARRIS, Department of Entomology, Purdue University, West Lafayette, Indiana 47907.—Propolis, or "bee glue", is a substance collected by the common honeybee (*Apis mellifera*) from natural sources and used to seal cracks and holes in the hive. The antibacterial action of this substance has currently received much attention. This study investigates this antibacterial action and the thermostability of propolis.

Extracts of fresh propolis in water and alcohol were boiled for five minutes to test the thermostability. The fractions and appropriate controls were incorporated into nutrient agar plates. The plates were then streaked with *Staphylococcus aureus*, *Bacillus cereus*, *Bacillus cereus* var. *mycoides*, *Pseudomonas fluorescens* and *Micrococcus lyso-*

deikticus. The plates were incubated at 37°C. Observations were made and results recorded at 12-hour intervals for three days.

Alcohol extracts proved to be bactericidal or strongly bacteriostatic against all of the organisms while alcohol alone had no such effects. The water extracts had a slight bacteriostatic effect against *Bacillus cereus* var. *mycoides* and *Micrococcus lysodeikticus*, with little or no effect on the other organisms. In all cases, the active agent was thermostable.

The Ecological Relationships of *Ephoron album* (Say) and *Ephoron leukon* Williamson (Ephemeroptera: Polymitarcidae) in the Tippecanoe River. LOUIS H. DERSCH and W. P. MCCAFFERTY, Entomology Department, Purdue University, West Lafayette, Indiana 47907.—The only two North American species of the burrowing mayfly genus, *Ephoron*, *E. album* and *E. leukon*, have been taken together in the Tippecanoe River. Since this was the first time such coexistence had been known for these sibling species, the opportunity was taken to study the phenomena of habitat adaptation, breeding isolation, and any character displacement which might be involved.

Main objectives of the research were (1) to discover how the larvae may subdivide the habitat, (2) to ascertain the method by which reproductive isolation is maintained, and (3) to compare the biologies of the two species in both sympatric and allopatric zones.

A compartmentalized laboratory aquarium was used to determine substrate particle size preference of the larvae of each species. Results showed that *E. album* would utilize a finer substrate than that preferred by *E. leukon*. This was essentially substantiated by field sampling.

Adults were collected with lights. Field data from summer, 1974, suggested temporal isolation, with *E. leukon* emerging earlier in the season.

Indiana Species of Diptera Genera Containing Aquatic or Semi-Aquatic Stages. B. L. HEATH and W. P. MCCAFFERTY, Entomology Department, Purdue University, West Lafayette, Indiana 47907.—As part of an endeavor to broaden our understanding of the aquatic insect fauna of Indiana, this study was undertaken to assemble in a single list the species of aquatic and semi-aquatic Diptera of the state. The study is based on literature records and the examination of specimens at Purdue University's Laboratory of Insect Diversity, the Illinois Natural History Survey, and the University of Michigan Museum of Zoology.

Over 700 species representative of 22 families are recorded. Since many immatures of these species are unknown and since habitat data are scarce, all state species of aquatic genera are listed but distinguished when only tentatively aquatic. It is assumed that as knowledge of the Diptera increases this preliminary list will be greatly expanded. The list should, however, provide a needed working base for aquatic biologists and entomologists.

The Mayflies (Ephemeroptera) of Indiana Project. A. V. PROVONSHA and W. P. MCCAFFERTY, Entomology Department, Purdue University, West Lafayette, Indiana 47907.—Over the past four years, the Lab-

oratory of Insect Diveristy staff has conducted an in-depth study of the mayflies of Indiana. This continuing project has added much to our understanding of the geographical and temporal distributions, habitat preferences, behavior, and taxonomy of this order. The study is also intended to provide needed base-line data for the analysis of environmental quality of fresh water systems throughout the state. To date, 110 species have been taken in Indiana, including three undescribed species and one undescribed genus. In addition, through extensive rearing efforts, many previously unknown larvae have been successfully correlated with known adults. Many new and improved sampling and rearing techniques have also been developed during the course of this project.

A History of Entomology in Indiana. B. ELWOOD MONTGOMERY, 906 North Chauncey Avenue, West Lafayette, Indiana 47906.—The accounts of conditions in Indiana by early travelers and settlers noted the abundance of mosquitoes, bedbugs and other annoying pests as well as those attacking field crops as timothy and corn. One or two biologists (Audubon, Rafinesque or Wilson) have made some explorations in Indiana during territorial days, and Thomas Say, the "Father of American Entomology", traveled down the Ohio River in 1819 and crossed the state from Ft. Wayne to Chicago in 1823 en route to his western trips, but there appears to be no entomological results from any of these early visits in the literature. Say came to New Harmony in January, 1826, and remained there until his death in 1834. His later papers include many Indiana records.

After the death of Say it was 50 years until there was another "full time" entomologist in the state. In 1884 F. M. Webster came to Lafayette as a Special Agent of the U. S. Department of Agriculture and Consulting Entomologist of the Purdue University Agricultural Experiment Station and James Troop came to Purdue as Head of the Department of Horticulture and Entomology. However, there were several "amateur" entomologists, whose activities were probably more or less confined to collecting. These included George Mitten who came from England to Goodland in 1875, R. J. Weith who came from Germany to Elkhart in 1865, Samuel G. Evans a native of Virginia who arrived in Evansville about the time of the close of the Civil War and Dr. T. G. M. Levette who was employed in the office of the State Geologist for several years beginning in 1869. All of these men, and possibly some others accumulated insect collections but most of them seem to have been lost or destroyed except a large collection of beetles made by Lavette. This was purchased by T. L. Casey in 1890 and presumably went to the National Museum at Casey's death, but as the specimens, or almost all of them carried no date or locality labels they cannot be identified.

Many papers have been published on the history of Entomology in Indiana. In 1966 a rather expensive account was presented to the Academy as a part of its observation of the sesquicentennial of Indiana statehood. As part of the Academy's bicentennial activities this is being updated and amplified. It is planned to include in it lists of all entomolo-

gists who ever worked in the state, of all who received entomological training in Indiana institutions, of all federal, state and other agencies which have engaged in entomological activities, and of the important entomological "event" as insect outbreaks, dates of first appearance of introduced species, etc. Attached will be a list of the taxa described by Thomas Say.

A Coordinate Indexing System for Ecosystematic Data^{1, 2}

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Abstract

A procedure for information storage and retrieval of ecosystematic data associated with the Ephemeroptera of Indiana collections at Purdue University consists of a modified coordinate indexing system. The system presently incorporates data based on 114 species and over 11,000 specimens, representative of many water systems throughout 90 Indiana counties. Over 1,800 accessions and 880 data uniterms have been utilized. An average of 54 individual accessions are referenced per uniterm for over 47,000 reference inputs. The system is adaptable to electronic data processing.

Introduction

The need for developing modern information storage and retrieval systems for data associated with systematics collections has become imperative (7). National data standards are currently being developed through the auspices of The Association of Systematics Collections to ensure a utilitarian network for electronic data processing. The urgency for the development and incorporation of electronic data processing-information retrieval systems (EDP-IR) is based primarily on the overwhelming quantity of data, and a growing awareness of the actual and potential applications of collections data for solving environmental problems. In order to establish baselines and decipher changing environmental patterns and ecological associations of species, methods of indexing and correlating the multitude of factors involved must be available as part of the collections storage system itself. Moreover, Squires (10) has adequately argued for the necessity of data processing merely from the standpoint of collections management for systematic research. For an example of the many types of current EDP-IR projects dealing with systematic biology, see Crovello and MacDonald (5).

In 1975, a project was initiated at Purdue University by the Laboratory of Insect Diversity in conjunction with the Water Resources Research Center to implement a system for processing data relevant to the natural geographic and ecological distribution of freshwater macroinvertebrates of Indiana rivers and lakes. The system was designed to provide the needed capability for correlating available subsets of environmental data from which various degrees of biological predictiveness of environmental quality could be derived and to insure that growth and maintenance of the system would be relatively simple.

Sampling of Ephemeroptera, or mayfly species, from throughout Indiana has been underway since 1971 in order to gain an understanding of the ecosystematics of this relatively large group of ecologically im-

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portant, benthic, primary consumers. The Indiana Ephemeroptera collection housed at Purdue currently includes 114 species and over 11,000 specimens. These collections are representative of 90 counties in the state, approximately 220 rivers and/or streams, over 60 lakes and/or ponds, all seasons of the year, and various degrees of water quality. The Ephemeroptera collection and associated data were therefore available as a prototype for the development of an environmental information and retrieval system. The limited Indiana Ephemeroptera housed at the Illinois Natural History Survey have also been included in the system.

The Coordinate Index

A coordinate indexing system (6, 11, and 12) was designed to manipulate taxonomic and ecological data, and also to incorporate the systematics collections with their inherent heirarchical makeup as part of the overall system. Broadhurst (3) described coordinate indexing as a convenient and useful method of referencing bibliographic data. Additional modifications and applications have provided a unique system with many practical advantages when used to encompass structured systematics collections data. The design and operation of this coordinate indexing system is detailed below in terms of three basic components.

1. Biological materials and associated data: Each vial of stored specimens (Fig. 1) represents a unique combination of a particular species taken at a particular time and place, and associated with particular ecological conditions. This automatically precludes the usage of any materials that have not been thoroughly sorted, identified, and verified by an authority. Data labels remain with the specimens at all



FIGURE 1. Items consisting of individual vials of specimens and data.

times. Each vial therefore represents a unique combination of data. These vials are curated (8) and catalogued taxonomically via family, genus, and species. Each vial has been assigned a consecutive accession number which ties the biological materials directly to the second major component of the system, the accession index.

2. The accession index: This is a separate serial card or master file in which all of the data associated with any one unique "item" (vial in this case) whether it be taxonomic or ecological is tabulated on a single 5" x 8" card (Fig. 2). This index is ordered, however, irrespective of any classification or relationship of the data represented, but only according to the sequence of accession numbers assigned to the items as they are accessioned into the system.

Pseudocloeon anoka Daggy
Baetidae

1708

PU-LID

L, ML, S, F, M
Field Reared

INDIANA: Elkhart Co., Elkhart R.
1.2 mi SE Millersburg at County
Bridge, VI-25-1973,
W. P. McCafferty, A. V. Provonsna

M. Minno

Lotic
Riffle Area
Cobble Subst.
52 F - Water
12-18 cm Depth

FIGURE 2. *A master card from the accession index.*

In Figure 2 an example is given of the way in which the various data associated with an item are presented. In the upper left hand corner is the scientific name, including the familial classification, of the item followed by various abbreviations indicating the sexes and stages involved and whether or not the adult stage if present was actually associated with the immature stages via rearing experiments. Abbreviations are as follows: S = subimago, ML = mature larvae, L = all other larvae, M = male adult, and F = female adult. The accession number is located in the upper right hand corner of each card. Below the accession number, the institutional and divisional acronyms indicate place of deposition of the material. In the center of the card the locality label data is reproduced just as it appears on the locality labels with the specimens. The identifier's name is located in the lower left. Recorded habitat data is listed in the lower right.

3. The uniterm retrieval index: All of the data which can be derived from each accessioned item are "traced." That is, appropriate terms or phrases which delimit parameters are singled out; for example, a species name, a stream, a week of the year, a substrate type, etc. These key words or phrases are called "uniterms" in the terminology of coordinate indexing (3).

Uniterms are used as individual headings to cards or sets of cards which make up the retrieval index. Under each appropriate heading the accession numbers of each item which applies are "posted" resulting in a complete system of cross indexed data. Perusal of any uniterm card provides the accession numbers of items applicable to the parameter described by the uniterm itself. For two or more uniterms, uniterm cards can be compared for coincidences of accession numbers, a procedure which in principle is similar to an "optical coincidence system" (1). Proceeding with such cross matches will thus yield reference information with various desirable degrees of complexity. For instance, one might wish to show what species occur in Indiana rivers, or in the other extreme, one might wish to know what species of *Stenonema* are known from riffle areas of Little Pine Creek as mature larvae from the month of June, etc.

If the uniterm retrieval index is to be operated without machine search (as is currently the case at Purdue) the following card design in the uniterm retrieval index is convenient. The 5" x 8" cards (Fig. 3) consist of a uniterm heading and ten columns numbered 0-9. Accession numbers are listed in the columns according to the last digit in accession number. This ensures more uniform usage across the entire card and facilitates comparison for coincidences of numbers on two or more cards. One requirement, however, is that the numbers must always be listed sequentially from smallest to largest in each column. To accomplish this all of the posting must be done at the time of accession so that interline insertions are avoided. With the present system the possible number of uniterms per item is known, and there should seldom be any need to retrace a sample for additional uniterms.

Nomenclature is subject to change. It is suggested that if such change occurs the item be reaccessioned with a new accession number. The old accession numbers can be voided or retained. If retained, the

Wabash River									
0	1	2	3	4	5	6	7	8	9
170	111	412	523	164	315	16	497	168	419
260	391	672	773	524	525	36	657	258	509
420	421	772	903	544	535	526	877	658	569
560	541	882	1073	784	545	536	897	758	629
780	621	902	1173	904	885	546	1067	838	659
880	1101	1072		954	905	786	1077	1068	1069
1070	1131	1132		1074	1155	876	1147	1078	1089
1100	1141	1142		1084	1355	1066	1157	1088	1139
1130	1171	1172		1114	1455	1076	1457	1148	1149
1140	1301	1242				1106		1158	1159
1160						1456		1168	1169
1170								1348	1299

FIGURE 3. A uniterm card with posted accession numbers.

prior master card should be retained in the accession index with a notation that a change has occurred. Perhaps the best method of handling this would be to mark the old number appearing on uniterm cards in such a way (e.g., with a circle or an asterisk) so that it is obvious that it no longer applies but still is available if the worker wishes to refer to previous data. For an item originally indexed only under the generic name, the specific epithet can be added to the master card with a new accession number appended to replace the old. For recombined names, the generic name and accession number can be changed. Accession number changes must always be duplicated in the collection itself.

There are currently over 1,800 accessions and 880 data uniterms, the cards for which occupy two double drawer file cabinets. An average of 54 individual accessions are referenced per uniterm for over 47,000 reference inputs.

The list of categories and subcategories in Table 1 should aid in visualizing the scope of possible uniterms and data. Some subcategories are actually uniterms within themselves and are noted with an asterisk. Uniterms for the category "Week of the Year" are merely listed as 1 through 52. Under the large category of "Ecological," data may or may not always be associated with specimens. Several categories are listed under "Precision of Data." Whether or not specimens have been field or laboratory reared or stages merely associated is important in the task of describing the larvae of a great number of species which remain unknown in the literature, but are important for the study of freshwater ecology (9). "State of Specimen Preservation" involves whether or not the specimens are fluid preserved in vials, placed on pins, or prepared on microscope slides. The vast majority of Ephemeroptera in North America are fluid preserved, and so far these are the only types which have been accessioned for Indiana.

TABLE 1. *List of uniterm categories and subcategories.*

GEOGRAPHIC	ECOLOGICAL
State or Country	Water System
County or Similar Unit	Water Classification
Exact Locality	Current Range
	Substrate Type
TEMPORAL	Temperatures
Year	*Nocturnal Light Attraction
Week or Year	
TAXONOMIC	PRECISION OF DATA
Family	Collectors
Genus	Identifiers
Species	*Field Reared
	*Laboratory Reared
	*Stages Associated
BIOLOGICAL	*Identified to Species
Sex	*Not Identified to Species
Growth Stage	Place of Deposition
	State of Specimen Preservation

Adaptability

Because the system is "open-ended," new categories and uniterms can be added. For example, if a collection from a river survey were to be added with very detailed limnological data (e.g., physical and chemical parameters measured at river sites) these data could be accommodated by adding new uniterm cards.

The efficiency of the system is directly related to the comprehensiveness of the data incorporated. It is also limited by the complexities of manipulation which increase as data input increases. At present the manual search system is most applicable to collection programs of limited scope and which have limited access to EDP hardware. In time, it may become practical to employ computer methods to make searches. The question of when an EDP system is justified is discussed by Crovello (4) in terms of costs and benefits. Arnett (1) suggested that if file cards are used for more than three years, then EDP is more effective.

Although manual search appears adequate for now, the system is adaptable to a long range goal of computerization which will be necessary for increasing retrieval efficiency as the data base expands (e.g., to include the mayflies of North America). Data standards as presented by the ASC council on standards for systematics collections (2) have been met. Terminology associated with the coordinate indexing system are equivalent to the proposed "standard" EDP terms. A uniterm category (and subcategory) is equivalent to a *data element*. A uniterm is equivalent to a *data item*. A vial of specimens (in this case) containing a species from a unique space and time and all data associated with it are equivalent to an *item*.

Basic data has been defined as "data with a high probability of use and desirability of use in all of the separate discipline-wide centralized EDP systems for information retrieval" (2). The itemized standards for *basic data* have been met or are inherent in the present system. PU (Purdue University) is suggested as an institutional identifier and LID (Laboratory of Insect Diversity) an institutional subdivision; the accession number is suggested as the individual number; and the data types of taxonomic identifier, locality, and time, are self evidently included. The state of the specimen presently involves only the mode of preservation, since specimens should be assumed to be whole and in "usable" condition unless otherwise noted (i.e., no uniterm expressing partial specimen representation has been necessary so far).

Applications

Although it is not the intention of this paper to deal with data analysis per se, three examples of the types of questions that may generate useful answers follow:

1. Which species of Ephemeroptera have been taken during 1971-1975 in a two-mile stretch of Wildcat Creek, Indiana, the immediate effluent area of an impending impoundment? The pre- and post-impoundment analysis would be greatly aided by having baseline data already established and retrievable. In fact, the coordinate index system was

recently utilized by Stanley Environmental Consultants in developing an environmental impact statement for Wildcat Creek for the U. S. Army Corps of Engineers.

2. Which species of Ephemeroptera could be expected as mature larvae in early June in littoral zones of small lakes and ponds in LaGrange, Steuben, Noble, and DeKalb Counties? If such species are found to be conspicuously absent in certain of the lakes of this region and season, this empirical relationship may justify further environmental analysis of cause and effect.

3. In what streams in an area of known distribution is found species X, whose range of tolerance for dissolved oxygen or some other factor is known to be quite low? Some biological assessment or suggestion of the water quality of certain streams could be made in part from the data.

The above examples deal with ecological applications of the data. The possible systematic applications of collections data are many and these have been dealt with in the literature (e.g., 10).

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Preliminary Studies on the Pathology Caused by *Mermis nigrescens* Duj. in Orthoptera

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Abstract

Parasitic *Mermis nigrescens* Duj. juveniles may cause tissue damage during migration within the host. As these juveniles develop, they may cause tissue distortion, underdevelopment of structures, and mechanical damage to tissue. Mechanical damage by the parasite may act to reduce the number of eggs laid by the host grasshopper.

Introduction

The importance of mermithids as a possible means of biological control of insect pests has been recognized by a number of investigators (1, 6, 10, 11). The United States Bureau of Plant Industry has used *Agamermis decaudata* and *Mermis subnigrescens* in an effort to control grasshopper populations. The government has also used members of the Mermithidae to control mosquito populations in the Arctic (2). Japanese investigators have reported that mermithids, parasitic in the rice borer, help to keep this pest within bounds (7, 12).

The purpose of this paper is to present some of the initial observations on the damage that *M. nigrescens* causes to the internal tissues of several host species of Orthoptera. These observations will be used to determine the extent of damage caused by the parasite and how this damage may play a role in the biological control of economically important Orthoptera.

Methods

All grasshoppers in this study were sacrificed using ethyl ether, then fixed in Bouin's fixative, washed in several changes of 50% ethyl alcohol, one change of 70% alcohol containing one per cent potassium acetate, and dehydrated according to the Martignoni (9) methyl benzoate method. Specimens were doubly infiltrated in a vacuum paraffin oven. Embedding was done in 56-58°C Paraplast (Fisher Scientific Co.). Specimens were sectioned at eight and ten microns and stained with Heidenhain's iron haematoxylin and eosin or Mallory's triple stain.

Results

Early infections by *Mermis nigrescens* juveniles appear to have little or no visible effect on the behavior of the host grasshopper. A few parasitized hosts showed some signs of immobility. In experimental infections where more than 70 eggs were fed to nymphs, few visible indications of infections were observed. However, it is assumed that numerous perforations of the intestine occur in multiple infections, but apparently these perforations seldom cause any dangerous infection or damage. In one experiment, seventy eggs were fed at one time to 52 host grasshoppers. Since 49 of these hosts survived past the 20th

day of infection, it appears that no major damage occurs to grasshoppers due to multiple penetration of the gut by the parasite. The 49 grasshoppers when dissected had from 1 to 47 parasites present. The largest number of parasite juveniles found in naturally infected grasshoppers was 67 in a female *Melanoplus femurrubrum*.

Generally, there is no macroscopic external indication of an infection. Johnson (8) reported that chironomids parasitized by *Hydromermis contorta* have a pale body instead of the usually bright red body. Christie (2, 3) observed no color change in parasitized grasshoppers, and infected specimens in this study supports that observation. Wheeler (13) noted numerous morphological changes in ants parasitized by mermithids, but apparently none of these changes are present in grasshoppers infected by *M. nigrescens*. A number of exoskeletons of normal and infected grasshoppers were mounted and observed microscopically. No apparent differences were noted.

Parasitic juveniles apparently do not overwhelmingly prefer any particular portion of the haemocoel or other body structures. Johnson (8) reported that *Hydromermis contorta* prefers the posterior portion of the chironomid body until late in the infection when the disappearance of the fat bodies at the anterior end of the host provides the parasite with added space in that region. However, *M. nigrescens* seems to migrate throughout the body of its host. It is not unusual to find young juveniles looped around the tentorial arms, among the mandibular adductor muscles, in the metathoracic leg, and penetrating the dorsal and ventral diaphragms of the insect host.

The mandibular adductor muscle of grasshoppers consists of several bundles of fibers. When a parasitic juvenile is present in the bundles, the bundles appear to be atrophied and highly compressed. In areas where the parasitic juvenile has penetrated the dorsal musculature of the body wall of the abdominal region of the grasshopper, the muscles become compressed or atrophied, and individual muscle fibers may be destroyed.

Often a portion of the parasite's body may be found penetrating the region of the brain. In such cases the protocerebrum or deutocerebrum or both appear atrophied and misshapened. This may affect normal mobility as noted by other workers (2, 8).

Penetration by the parasite of the salivary glands results in these structures being markedly reduced. The destruction of much of the fat body is evident in most infections and may play a role in the metabolism of the parasite (5). Johnson (8) reported similar observations in chironomids parasitized by *Hydromermis contorta*.

When a parasite is lying apposed to the gut wall, that immediate area of the gut appears to be thinner than a comparable area where no parasite is present. There is evidence that the outer layers of the gut have been destroyed due to the parasite's presence. Adjacent areas of the gut often appeared greatly thickened.

Many examples of mechanical distortion of the gut and lateral oviducts were encountered. This distortion consisted of compression and partial closure of the lumen of these structures due to crowding of the parasite against the outside walls.

Christie (2) stated that in every case where he had examined an adult female *Melanoplus femerrubrum* parasitized with *Agamermis decaudata*, the ovaries were reduced in size and in many cases were vestigial. He stated that similar results were found in grasshoppers parasitized by *M. subnigrescens* (3).

Many parasitized female grasshoppers were examined histologically as well as *in toto* in this study. *M. nigrescens* were usually found in the area of the ovaries and were often found threading their way between individual ovarioles. This usually caused individual ovarioles to become reduced in size. In no instance, however, were they ever found in the condition illustrated by Christie (2, figure 13). Nevertheless, it is felt that one of the factors causing a reduction in the number of eggs laid by infected hosts is due to mechanical damage done to the ovarioles by the parasite.

Parasitized males showed very little difference in the development of the testes when compared to normal males. Christie (2) is of the opinion that most, if not all, parasitized male grasshoppers are capable of producing spermatozoa and the evidence from this study tends to support this opinion.

Several specimens of grasshoppers carried a mermithid which had penetrated the neurolemma. In these cases, the parasite was apposed to the nerve cord and some apparent damage to the nerve cord itself was observed. Reports that insects parasitized by mermithids lose their irritability or become immobile may be due to the parasite coming in contact with the nerve fibers by penetrating the neurolemma (2, 8).

Discussion

On the basis of this study, it appears that many internal structures of the host grasshopper suffer some damage due to the presence of *M. nigrescens*. In cases where damage to the reproductive organs occurs, there may be a reduction in the number of eggs laid. Mechanical damage, however, may not be the major cause of reduced egg production as shown by Denner (3). Additional studies, now underway, may indicate other pathological effects of *M. nigrescens* on Orthopterans.

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Insects and Other Arthropods of Economic Importance in Indiana During 1975.

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Abstract

The abundance and economic impact of selected arthropods responsible for crop losses, annoyance to man and animals, destruction of food and fiber products as well as the abundance and activity of selected entomological parasites and predators of importance in their control in Indiana during 1975 are discussed.

Introduction

As a prelude to the discussion of major insect activity, the more important meteorological influences on both invertebrate and plant life are reviewed. The winter of the 1974-1975 season was mild, with above-normal temperatures and normal or near normal precipitation (though with less than normal snowfall). March was cooler than normal and soils were wet as usual, but April and May were especially kind to growers. Plowing and the planting of corn, soybeans and small grains were completed far in advance of normal, and the rains which did occur interfered but little with the care and harvesting of alfalfa. Wheat at first appeared to have been hurt by the cooler-than-normal spring months, but most recovered. And pastures ranged from only poor to fair during April, and fell to that level again during the dry July period. Both corn and soybeans were above average in rate of growth and in maturing.

Topsoil moisture ranged from adequate to surplus until the end of June over most of the state. After that the crops suffered some moisture stresses for much of July over most of the state, stresses that were more severe in the southern half of the state, especially in the SC (south central) area, where parts were dry even into September. Most of the corn and soybeans were but little affected, however, and record crops were expected. The warm winter favored the corn flea beetle, but little damage was experienced due to this insect, probably because of the nature of the rainfall. Rains tended to be rather spotty, often accompanied by winds and even occasionally hail, and heavy rather than drizzly. This may have been a factor in the reduction of the first generation of the European corn borer, whose second flight came during the dry period in July in most of the state.

¹ Journal Paper No. 6109, Purdue University Agricultural Experiment Station. The following includes those who have made identifiable contributions to this summary: Leland Chandler (Hymenoptera, cattle and sheep insects), James Clark (Nurseries, parasite release data, Japanese beetle), Richard C. Dobson (Cattle insects), C. Richard Edwards (Soybeans, alfalfa), John Favinger (*Alphitobius*), Virgil Knapp (Identification of Aphids), Philip T. Marshall (Forest insects), David L. Matthew (Extension data), Darryl P. Sanders (Diptera of man and animals), Richard Schoenbohm (Black cutworms and their parasites), Donald L. Schuder (Ornamentals), Richard E. Shade (Aphids), John O. Sillings (Extension data), Omelio Sosa (Wheat), Walter L. Stirm (Weather and crop data), F. Thomas Turpin (Corn soil insects), Gordon Vanwoerkom (Corn rootworms), and Alan C. York (Vegetable insects).

Harvesting of crops ran far ahead of normal; the early wheat harvest made possible an increase in second-cropping, which resulted in extended feeding periods for the Mexican bean beetle.

Corn and Small Grains

In addition to favorable weather, corn growers enjoyed relative freedom from serious insect attack. The summer population of the European corn borer (*Ostrinia nubilalis* [Hübner]), for instance, was the lowest in the 5-year history of the survey. Only 4 of the 12 corn survey districts had more than 1 larva/100 plants—the extreme north portions of the NW (1 larva), the NC (4), the SW and south portions of the SE (1 each). The state average was 0.9 borer larvae/100 stalks, with but 2.5% of the stalks infested. The fall population averaged 33.9 larvae/100 plants, higher than 1974 but still below the 10-year average. Only the extreme north portions of the NE and the SW districts exceeded the 10-year average.

The corn leaf aphid (*Rhopalosiphum maidis* [Fitch]) probably arrived too late to heavily infest the corn; of the 2550 stalks examined over the state from 14-29 July only 7.1% were infested, the lowest number since 1972. (57% of the corn had reached the green-silk stage this year, as compared with 37% at the time of the survey in 1974). The aphid populations observed in the fall survey differed little from those of 1974; 26.49% of the 4700 plants examined in 1975 were infested as were 25.95 in 1974. There were several indications, however, that it was a favorable year for aphids on corn. Where corn of the appropriate age was available, numbers of aphids were much higher than last year. And when colonies were able to form, they persisted for longer periods of time than usual. The oat bird-cherry aphid, (*Rhopalosiphum padi* [Linnaeus]), was often present and sometimes in great numbers on corn in the NC and NE districts at the time of the fall survey. And almost every plant in a WC district corn field had a colony of the potato aphid (*Macrosiphum euphorbiae* [Thomas]), during the summer.

Besides the kernel feeding that was done by the European corn borer, kernel feeding by the corn earworm (*Heliothis zea* [Boddie]) and the fall armyworm (*Spodoptera frugiperda* [J. E. Smith]) was included in the fall, 4700-stalk survey. This was also less, probably because the corn matured before the arrival of the moths. Only 2.5% of the plants were infested (3.6 in 1974), with a loss of 0.028% of the crop (0.037% in 1974). Of the 58 larvae still present in the ear at the time of the survey, 93% were corn earworms (as were 62% in 1974). Feeding by birds on the kernels, which usually occurs in the milk stage, was also less than the ten-year average of 8.2%. Only 3.5% of the ears had been molested by birds, resulting in a loss of 0.117% of the crop (Average: 0.4%).

No concerted effort was made to follow the expansion of the area occupied in the state by the western corn rootworm (*Diabrotica virgifera* [LeConte]) during 1975, and little was expected. Over the years the pattern has been one of expansion 1 year, consolidation the

next, apparently because it takes about a year to cross a county. Nevertheless this year adults were taken in 3 new counties. The Knox county record possibly represents a new invasion from Illinois, as the nearest infested Indiana county was 80 miles away. The Delaware and Randolph county records likely represent eastward movements from contiguous Indiana counties. There were declines in the number of adults observed during the summer survey in the NW (the northern half of the NNW district), the NNE and NC, no change in the NNC and a slight increase in the NW (the southern half of the NW district). (There were none in the other districts).

Despite widespread appeals for information on rootworm-damaged fields, few were reported, nor were any observed with obvious symptoms during the fall corn survey.

The first adult of the season was observed on 7 July in Tippecanoe Co., and adults were still emerging from the ground through September in Porter County.

The northern corn rootworm (*Diabrotica longicornis* [Say]) caused only negligible injury to corn. Adults were found in a smaller percentage of the fields north of Indianapolis and a larger percentage south of that city, than in 1974, during the corn survey. The first adult taken in a BL (Blacklight) trap was taken 21 June in Vanderburgh Co.; the first adult seen in the field was observed 2 July in Tippecanoe County.

There was also a decline in the percentage of fields in which the southern corn rootworm (*Diabrotica undecimpunctata howardi* Barber) was observed except in the SSE district.

Appeals for information leading to fields of corn damaged by the black cutworm (*Agrotis ipsilon* [Hufnagel]) led to no more than 400 acres of possibly infested land spread over the state. The larvae of this species normally attack only in spots in a field, and in such spots, they can be devastating; probably no more than 100 acres were involved in such spots, with damage running from 10 to nearly 100%.

There were also some unusual infestations in corn grown for grain. In Jackson County a field of 13 acres was two-thirds destroyed by variegated cutworm (*Peridroma saucia* [Hübner]) larvae; the field had been in wheat in the spring of 1974, seeded to red clover after the harvest and planted no-till in 1975 to corn.

Damage to seedling corn by larvae of the redheaded flea beetle (*Systema frontalis* [Fabricius]) was confirmed for the first time in Indiana. From 5 to 40% of the plants in spots in a 90-acre field in Vanderburgh Co. were severely damaged, resulting in many instances in their death. The infested plants were most common in about 40 acres of the field and in these spots 30-40% of the plants were lost. Larvae entered the stem slightly below the surface of the soil and excavated the heart of the 5-6" plants above and below that point, by 5 June. Up to 10 larvae were counted in and around the plants, but generally only 1-2 were present in and around each plant in the infested spots.

For a new state and a new county record, the southwestern corn borer (*Diatraea grandiosella* Dyar) was collected for the first time in

Indiana from corn growing in Vanderburgh County (Union Township). This pest has been present for years in the Kentucky counties south of Vanderburgh and Posey, and in Illinois west of the latter county. Its presence in a stalk usually means the loss of the ear the stalk bears; the larvae have a habit of girdling the stalk just before they enter their hibernation site at the tip of the tap root, so that a touch or a good wind will snap the stalk about a half-foot above the ground or lower. It is not expected to move much further north, as it hasn't done so in Illinois, and as yet has infested less than 1% of the stalks here.

Sorghum, which customarily attracts and can support large numbers of corn leaf aphids, was this year almost free of them in the sorghum seen in Vigo and Knox counties. The greenbug (*Schizaphis graminum* [Rondani]) appeared in the same area, almost always in small dime-to-dollar patches scattered mostly at the edges of the field, always in non-economic numbers, and often outnumbered by the yellow sugarcane aphid (*Sipha flava* [Forbes]).

No economic infestations by the cereal leaf beetle (*Oulema melanopus* [Linnaeus]) were observed on small grains, and specimens were generally hard to find. Chinch bugs (*Blissus leucopterus* [Say]) were absent or in negligible numbers, and the Hessian fly (*Mayetiola destructor* [Say]) remained at low levels in wheat. The state average percent infestation for all varieties was 0.9, the state average number of puparia/100 stems was 1.1. This year 14% of the fields had infestations as against 2% in 1974. Seven fields (of 307) had percentage levels greater than 10%, the highest being 24%. And although armyworms were found in roadside grasses, in wheat, and in grassy alfalfa in many areas of the state, they were rarely of economic importance anywhere.

Forage Legumes and Soybeans

Two insects were of major importance on Indiana alfalfa. Alfalfa weevil (*Hypera postica* [Gyllenhal]) larvae were present at the rate of 4.7/2.6" stem (81% first instar) in 1 SW district field by 14 April. By 21 April (equivalent 1974 data in parentheses) seven SW district fields which averaged 4.7" (8.0") had 5.9 (4.5) larvae per stem. Thus this year's crop had more larvae on alfalfa little more than half as tall. As in past years treatment was necessary on early all SW, SC and SE fields. In the central districts treatment would have been economic on many fields south of Indianapolis; damage was often evident north of Indianapolis, but treatments were seldom warranted. In the northern districts most growers had the option of cutting early instead of treating, but some action was usually necessary; when the cutting option was exercised stubble sprays were sometimes necessary. The potato leafhopper (*Empoasca fabae* [Harris]) was again the more serious of the alfalfa pests, and throughout the state controls were generally necessary on every cutting but the first. Controls were recommended when populations reached 1/sweep, which is now believed to be somewhat above the economic level. The alfalfa caterpillar (*Colias eurytheme* Boisduval) was never economic by itself,

in alfalfa, but teamed with the potato leafhopper they together occasionally formed an economic aggregate in the northern districts. The same was true of the pea aphid (*Acyrtosiphon pisum* [Harris]), especially in conjunction with droughty periods.

The Mexican bean beetle (*Epilachna varivestis* Mulsant) sometimes caused conspicuous damage to alfalfa even when soybeans were available and were swept at the rate of 2 or more/sweep; they were of little consequence in that crop. They were much more common this year than for several years, and caused spotty damage all over Indiana south of US 40 except in the sandier areas near Illinois. As is typical of the insect, damage was usually more severe in fields near woods such as those tucked away in the hills in Clay and Owen counties: leaf loss ran to 35% in such fields, with patches that had 100% defoliation. There were important losses however even in large fields more distant from woods. Treatment was indicated in some situations, but probably a lot of insecticides were used more for insurance than need.

Unusual this year was the number of fields that were infested by the soybean thrips (*Sericothrips variabilis* [Beach]). The insect is usually present in small numbers, but this year it reached economic proportions, with up to 50% of the leaf surface affected in some SW district fields, and was evident by its numbers as far north as Clay and Owen counties, where numbers did not usually exceed 30/trifoliolate. Unfortunately there was also a lot of herbicide damage about, and the thrips were often blamed when herbicides were at least partially responsible.

Little damage was attributable to the green cloverworm (*Plathypena scabra* [Fabricius]) in soybeans, but numbers were greater this year than last, and with little evidence of disease or parasitism, they appear to be building in numbers.

Wireworms (Unidentified species) caused such extensive damage to a 40-acre field of soybeans that replanting was necessary (Green Co.).

The Japanese beetle (*Popillia japonica* Newman) removed 25% of the leaves in a 5 square mile area in Kosciusko and Noble counties, resulting in near-economic defoliation. Adults of this species were collected in bait traps in Franklin, Ripley and Crawford counties, all new county records.

Vegetable Crops

Mexican bean beetles were even more of a pest in garden beans than in soybeans; and in a 45-acre commercial field of snap beans in Jackson Co., they were responsible for an average of more than one lesion/pod, rendering the field useless. The diamondback moth (*Plutella xylostella* [Linnaeus]), the imported cabbageworm (*Pieris rapae* [Linnaeus]), the cabbage looper *Trichoplusia ni* [Hübner]), and the striped flea beetle (*Phyllotreta striolata* [Fabricius]) (all as larvae except the last) were all present in a field of cabbages in Tippecanoe Co. in early July at the rate of about one each/cabbage. In other gardens in the same county the crossstriped cabbage worm (*Evergestis rimosalis* [Guenée]), in numbers equal to or greater than

those of the imported cabbageworm, together were causing extensive damage to collards, broccoli, cauliflower and cabbages. The crossstriped was also reported from Clay county gardens, but not in economic numbers; this insect has not been reported from this area very frequently, nor has the southern cabbageworm (*Pieris protodice* Boisduval and LeConte), larvae of which attacked a single cabbage in a field in Tippecanoe Co.

The striped cucumber beetle (*Acalymma vittata* [Fabricius]) was less of a pest in cucurbits this year than usual.

In a field in Johnson Co. in mid-August, 10 to 15 tomato hornworm (*Manduca quinquemaculata* [Haworth]) larvae/100 sq. ft. seriously damaged ripe tomatoes.

The absence of aphids in 3 commercial pepper fields in Floyd Co. in an aphid year is noteworthy. In 1974 control could not be obtained even with chemicals; this year there were few or none even though chemicals were not used.

Ornamentals, Forest and Shade Trees

Forest tent caterpillars (*Malacosoma disstria* Hübner) infested about 1000 acres of oak woods in the NW corner of Lawrence Co. and nearby areas, with defoliation of the upper story in patches of up to 100 acres.

A scolytid beetle (*Xylosandrus germanus* [Blandford]) infested 30-40% of 7000 30" tall walnut trees in a Fountain Co. plantation. The species had been collected before, according to literature, from Jefferson Co., and there is a single specimen in the Purdue insect collection from Dubois Co.

The cypress twig gall (*Taxodiomyia cupressiananassa* [Osten Sacken]) was collected from cypress in Tippecanoe and Clay counties, both new county records. It had previously been taken only from a few counties bordering the Ohio River.

There is no evidence yet that the large numbers of adults of the spruce budworm (*Choristoneura fumiferana* [Clemens]) and the jack pine budworm (*C. pinus* Freeman) that were dumped by the winds in 1974 on northern Indiana succeeded in establishing colonies.

The fall cankerworm (*Alsophila pometaria* [Harris]) caused extensive damage to a variety of forest and shade trees north of South Bend, in St. Joseph County, early in June.

The fall webworm (*Hyphantria cunea* [Drury]) population centered this year in the NC district.

Two other insects were reported this year which have seldom if ever been reported from the state before. The iris weevil (*Mononychus vulpeculus* [Fabricius]) from iris in Tippecanoe Co., and the red-backed cutworm (*Euxoa ochrogaster* [Guenee]), larvae of which were collected from petunias in Lawrence Co. in July.

The 11 most commonly reported arthropods as observed by nursery inspectors during 1975 are listed below:

1. Bagworm (*Thyridopteryx ephemeraeformis* [Haworth])

2. Maple bladdergall mite (*Vasates quadripedes* Shimer)
3. Fall webworm (*Hyphantria cunea* [Drury])
4. Bronze birch borer (*Agrilus anxius* Gory)
5. Oystershell scale (*Lepidosaphes ulmi* [Linnaeus])
6. Euonymus scale (*Unaspis euonymi* [Comstock]) and Fletcher scale (*Lecanium fletcheri* Cockerell), reported an equal number of times.
7. Cooley spruce gall aphid (*Adelges cooleyi* [Gillette])
8. Mimosa webworm (*Homadaula anisocentra* Meyrick)
9. Yellownecked caterpillar (*Datana ministra* [Drury])
10. Birch leafminer *Fenusa pusilla* [Lepeletier])

Man and Animals

Mosquitoes achieved prominence in 1975 due to their association with two strains of encephalitis, the St. Louis and the California. More Indiana citizens fell victim to these arthropod-borne viruses than in any previous year in which records have been kept.

This was also a year for deer flies (*Chrysops* sp.) which were so numerous, according to a Warren Co. source, that they drove cattle from the shelter of the woods, in mid-June. The American dog tick, (*Dermacentor variabilis* [Say]), on the other hand, returned to normal or subnormal numbers from last year's peak. Records for the months of July and August only put the face fly (*Musca autumnalis* De Geer) at peaks of about 15/face the last week of July and the first week of August, and the horn fly (*Haematobia irritans* [Linnaeus]) at about 200/animal during the month of August.

The first adult sheep bot fly (*Oestrus ovis* Linnaeus) was observed 2 July in Warren Co. The cattle biting louse (*Bovicola bovis* [Linnaeus]) was so numerous in a herd of brood cows in Warren Co. and another in Tippecanoe Co. that by 9 May the hosts had large hairless patches.

Biting midges (*Culicoides variipennis variipennis* [Coquillett]) were biting in Washington and Dubois Counties on 22 April. This group of insects is seldom reported and it is recorded here mainly for that reason.

The following is a resume of inquiries received by Purdue extension workers between 1 October 1974 and 30 September 1975.

Of the arthropods that accidentally invade homes, spiders (several species) were the most frequently reported, but only in their usual numbers. Collembola (several species) were the next most frequently reported, this year at 3 times their usual rate. Diplopods were reported an average number of times but they achieved considerable notoriety in Floyd's Knobs (Floyd Co., in August) and Aurora (Dearborn Co., in June). What appeared to be a single species (determination not possible due to lack of specialists) invaded these communities in very large numbers.

An invasion by European earwigs (*Forficula auricularia* Linnaeus) disconcerted the inhabitants of a mobile home park in St. Joseph Co. early in August. To have reached the population size involved must have involved several seasons, the first evidence that the insect has overwintered in this area.

A case of a synanthropic commensal turned casual invader occurred in Jennings Co. when the lesser mealworm (*Alphitobius diaperinus* [Panzer]), which had bred in enormous numbers in the manure pits of a local poultry operation, migrated. Adults entered homes in objectionable numbers for distances up to 2.5 miles from the source.

Of the insects that share man's prepared foods the Indian meal moth (*Plodia interpunctella* [Hübner]) remains the one most reported, this year about twice as often as average, followed by the sawtoothed grain beetle (*Oryzaephilus surinamensis* [Linnaeus]), also reported an above average number of times.

Of the insects that damage homes, termites (*Reticulitermes* sp.) led the list followed by carpenter ants (*Camponotus* sp.), both reported an average number of times. Carpenter bees (*Xylocopa virginica* [Linnaeus]) were locally quite abundant.

Among the insects that attack man on occasion, yellow jackets (*Vespula* sp.) in 1975 held the place of prominence occupied in 1974 by the polistine wasps. And a case of a bite by the bloodsucking conenose (*Triatoma sanguisuga* [LeConte]) was reported from Jeffersonville (Clark Co.), the first in at least 6 years. The Purdue insect collection holds specimens from Lawrence, Orange, Crawford and Vanderburgh Counties, and it has been reported from Dubois Co. (1). Its reputed range covers the lower half of Indiana (1).

Beneficial Insects

The ichneumonid parasitoid *Bathyplectes curculionis* [Thomson] developed somewhat more slowly in 1975 than in the previous year. Eighty percent of the cocoons exposed to the environment in Knox Co. had pupated by 20 March, as compared with the same percent by the end of the first week in March, 1974. Only 10% had emerged as adults by 16 April in 1975, as against 50% by 12 April in 1974. Firm data are not yet available, but the rate of alfalfa weevil parasitization is certain to be much lower also than in 1974. Two adults of the mymarid egg parasite *Patasson luna* [Girault] were reared from a total of 1660 alfalfa weevil eggs held for hatching. The host eggs were from Randolph Co., and this represents a new county record. The eggs of the weevil were collected 24 March.

About 60% of the black cutworm larvae collected from corn and soybean fields between the end of May and early July were parasitized, mostly by the braconid *Meteorus leviventris* [Wesmael].

Perilitus coccinellae [Schrank] cocoons were observed in corn fields in Knox and Gibson counties on 10 June, the first of the season. Fresh cocoons were also present in corn fields in September. About 5% of the *Coleomegilla maculata* [De Geer] observed in corn fields in September were parasitized by this species, and 1 of the ten convergent lady beetles (*Hippodamia convergens* Guérin-Meneville).

The lady beetle *Coleomegilla maculata* was the most commonly collected lady beetle in alfalfa fields as well as corn fields. Adults appeared in 2 rotary traps throughout the summer in numbers no greater than 4 in one trap/48 hours except for the 48 hours ending on

19 September, when 27 were collected, on 29 September, when 210 were collected, and on 1 October, when 95 were taken; and in the other traps, no more than 6 except for 19 September, when 8 were collected, 84 on 29 September, 47 on 2 October, and 10 on 6 October. The traps were stopped on that date. No other coccinellid congregated in that manner between the end of May and the end of September, although one of the traps collected more on ordinary nights of both *Hippodamia convergens* and *H. parenthesis* Say than of *Coleomegilla maculata*.

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New Locality Records in the Genus *Chrysops* (Diptera: Tabanidae) in Indiana

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Abstract

Collection data including 35 new Indiana county records of deer flies (*Chrysops*) are reported.

Introduction

Burton (2) has provided the most recent list of Indiana *Chrysops* and a convenient base on which to add locality records. We have assembled 35 new county records resulting from state survey and extension activities.

Most of these *Chrysops* were collected by sweeping at head level with a net; nearly all collections were made at brief stops while traveling to other destinations, which accounts for the small size of the catch at each location.

In reporting, the county will be listed first, followed by the date (if 1975, that will be omitted), the number of ♀♀, other species of large biting flies taken with it, and the specific site. If the site is unusual or otherwise requires elaboration, a description follows only the first mention of it. New county records will be marked with an asterisk.

Chrysops aestuans Wulp, 1867. Jennings*, 18 VII 1974, 1, with *C. pikei*, *C. sequax* var. *tau*. Little Graham Creek joins Graham Creek just east of San Jacinto and near the junction of county roads 230S and 675E. All catches were made on Little Graham at this point. The banks here are steep, the bottom sandy. This record represents a considerable range extension of this species in Indiana; Burton (1) collected 2 specimens in Lake Co., and records it from Kosciusko Co. He felt less than confident about two published Kentucky records, but this present record would make them more probable.

Chrysops callidus Osten Sacken, 1875. Steuben, 10 VI 1970, 1. Whitley, 9 VI 1970, 1; 4 VI, 1, with *C. cineticornis* near a gravel pit which always has water in it in Columbia Twp., Sect. 32. Kosciusko, 9 VI 1970, 1. Pulaski, 29 VII 1974, 2, with *C. flavidus*, *C. montanus*, *C. pikei*, *C. vittatus*, Winamac Fish and Game Area. White*, 4 VI, 2, with *C. cineticornis* near Buffalo on Indiana 16 between the Tippecanoe River and Monon Creek, in the vicinity of a littered gravel pit. Grant*, 27 V. 1, near 800E and Indiana 26. Ripley, 18 VII 1974, 1, Versailles State Park. Jackson, 30 V 1974, 1. Washington*, 20 V. 1. Harrison*, 20 V, 1, Jerome Davis farm. Dubois, 19 V, 1, with *C. pikei* and *C. niger*. Pike*, 10 VI, 1, with *Tabanus molestus* and *T. mularis*, Patoka Fish and Game Area. All catches were made in the southernmost portion of this fish and game area, which can be reached by turning at the first entrance leading east after leaving Indiana 64. This portion of the park appears to have been converted from a strip mine to a park; the

waters are discolored, and vegetation, except for patches of trees, is sparse. Gibson, 10 VI, 1, with *C. pikei* and *C. flavidus*, a swampy area north of 125S on Indiana 65. Warrick, 19 V, 1, with *C. pikei*.

Chrysops cincticornis Walker, 1848. Whitley*, 4 VI, 1, with *C. callidus*, Columbia Twp., Sect. 32, gravel pit. A specimen was also sent to the Extension Office for determination, from this county. No other data were available except date, 6 VI 1973. White*, 4 VI, 1, with *C. callidus*, near Buffalo (site as described above).

Chrysops flavidus Wiedemann, 1821. Pulaski, 29 VII 1974, 1, with *C. callidus*, *C. montanus*, *C. pikei*, *C. vittatus*, Winamac Fish and Game Area. Gibson, 10 VI, 1, with *C. callidus*, *C. pikei*, a swampy area North of 125S on Indiana 65.

Chrysops impunctus Kröber, 1926. Warren, 4 VII 1973, 1, Black Rock Park. This record was reported earlier (2). Parke*, 8 VII 1974, 2, at roadside rest stop on Indiana 59.

Chrysops indus Osten Sacken, 1875. Steuben, 12 VI 1974, 1, swept from grass in Jackson Twp., Section 27. Kosciusko, 9 VI 1970, 1. Fulton*, 29 V, 1 sent in with 4 *C. niger* to the Extension Service by a woman who claimed allergic reactions following bites by either or both species. Grant*, 14 VI 1972, 1, collected from dog on farm at junction of Indiana 26 and 450E.

Chrysops macquarti Philip, 1961. Clay*, 17 VI 1974, 1. Franklin, 28 V, 1, junction Indiana 101 and Union Co. line, with *Symphoromyia pleuralis*. Ripley*, 11 VI, 2, with *C. montanus*, Otter Creek where it goes under US. 50. Jennings*, 19 VI 1974, 3; 11 VI, 2, all 5 from Little Graham Creek. Jackson*, 5 VI 1972, 1, Jackson Twp., Sect. 14E, east of Seymour.

Chrysops moechus Osten Sacken, 1875. White*, 22 VII 1974, 2, with *C. sequax*, Jct. Indiana 16 and Metamonong Creek. Tippecanoe, 28 VI 1970, 1; taken in large numbers by G. Finni and H. R. Lawson. Jennings*, 20 VI 1973, 3, Little Graham Creek; 19 VI 1974, 1, same site; 14 VIII 1974, 1, with *C. vittatus*, same site. Harrison*, no date, collected by K. Shepard of Hardinsburg, R. R. 1, where they were numerous. Martin*, 10 VI 1972, 2, Crane Naval Ammunition Depot grounds.

Chrysops montanus Osten Sacken 1875. Pulaski, 29 VII 1974, 1, with *C. callidus*, *C. flavidus*, *C. pikei*, and *C. vittatus*, Winamac Fish and Game Area. Ripley, 11 VI, 1 with *C. macquarti*, Otter Creek where it goes under US. 50. Brown*, 24 VII 1974, 1, T. C. Steele State Memorial Park.

Chrysops niger Macquart, 1838. Steuben, 12 VI 1974, 1, Jackson Twp., Section 27. St. Joseph, 12 VI 1974, 1, Union Twp. Section 29. Kosciusko, 9 VI 1970, 1. Fulton, 29 V, 1, sent to the Extension service with *C. indus* with complaints of allergic reaction to bites of one or both species. Cass*, 9 VI 1970, 1. Ripley*, 21 V, 1, Elrod. Jackson*, 12 VI 1970, 1, accused of causing allergic reaction by individual who sent it to Extension service; 24 V 1973, 1, Jackson Twp. Section 14E; 15 V, 4. Dubois*, 13 V, 2. Daviess*, 18 V, 2.

Chrysops pikei Whitney, 1904. Carroll*, 11 VI 1974, 1, Delphi city park. Pulaski, 29 VII 1974, 1 with *C. callidus*, *C. flavidus*, *C. montanus* and *C. vittatus*, Winamac Fish and Game Area. Randolph, 4 VI 1974, 1, Mississinewa River at Indiana 1. Delaware, 9 VIII 1971, collected by C. Pace, who complained of a large population. Union, 24 VII 1974, 1, waterworks west of Liberty. Howard, no date, collected by G. Kull. Kokomo, who complained of large numbers of bites producing welts, sent to the Extension Service. Shelby*, 28 V, 1, Big Blue River at Indiana 44. Bartholomew, 24 VII 1974, 1, a few miles west of Columbus on Indiana 46. Tippecanoe, 31 VII 1970, 1; 5 VII 1973, 1, collected by H. R. Lawson in BL trap Purdue Entomological Research Area. Warren*, 15 VII 1974, 1, Kent Twp.; 7 VIII 1974, 1, with *C. vittatus* and *Tabanus sackeni*, Kent Twp. Putnam, 12 VIII 1974, 1, with *C. vittatus*, Russell Twp. Section 1; 19 VIII 1974, 1, with *C. vittatus*, same site. Jennings*, 17 VI 1974, 1; 18 VI 1974, 1, with *C. sequax* var. *tau*, *C. aestuans*, both dates Little Graham Creek. Jefferson*, 17 VII 1974, 1, with *C. uni-vittatus*. Dubois, 19 VII 1973, 1, near Huntingburg; 17 VII 1974, 1, Robert Buchta roadside park; 19 V, 4, with *C. callidus* and *C. niger*. Warrick, 16 VII 1974, 1, Millersburg; 19 V, 1, with *C. callidus*. Gibson, 19 VI, 1, with *C. callidus*, *C. flavidus*, north of 125S and Indiana 65.

Chrysops sequax Williston, 1887. Newton*, 31 VIII 1970, 1, near Roselawn. White, 20 VIII 1971, 7, very numerous 5 miles west of Brookston, 22 VII 1974, 1, with *C. moechus*, Indiana 16 and Metamonong Creek. Parke*, 7 VIII 1974, 1, Green Twp. Section 7, junction Indiana 236 and Indiana 59.

Chrysops sequax variety *tau*, Philip, 1955. Jennings*, 18 VII 1974, 1, with *C. pikei* and *C. aestuans*, Little Graham Creek.

Chrysops vittatus Wiedemann, 1821. Marshall, 1 VIII 1974, 1, Old Tipp Town park. Pulaski, 29 VII 1974, 7, with *C. callidus*, *C. flavidus*, *C. montanus*, *C. pikei*. Howard, 9 VII 1974, Center. Hancock*, 25 VII 1974, 2. Bartholomew, 24 VII 1974, 1, with *C. pikei*, west of Columbus; 24 VII 1974, 3, Clifty Twp., a half mile east of Newbern. Tippecanoe, 14 VIII 1970, 1, Purdue Entomological Research Area, collected by H. R. Lawson. Warren, 15 VII 1974, 2, junction Indiana 28 and Indiana 63; 7 VIII 1974, 5, with *C. pikei* and *Tabanus sackeni*, Kent Twp. Montgomery, 10 VII 1974, 7; 23 VII 1974, 18, 7 VIII 1974, 2, all Scott Twp., Section 32. Putnam, 23 VII 1974, 1, junction U.S. 36 and U.S. 231; 12 VIII 1974, 17, with *C. pikei*, Russell Twp.; 19 VIII 1974, 10, with *C. pikei*. Parke, 8 VII 1974, 2, with *C. impunctus*, on Indiana 59, roadside table; 15 VII 1974, 1, same site. Owen, 23 VII 1974, 1, Montgomery Twp., Section 21, 1.4 miles north of junction Indiana 67 on Indiana 43, just south of Carp; 23 VII 1974, 1. Switzerland*, 18 VII 1974, 2. Jennings*, 14 VIII 1974, 1, with *C. moechus*, Little Graham Creek. Jackson, 29 VII 1970, 1.

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2. MEYER, ROBERT W. 1973. [In] Cooperative Economic Insect Report 23(28):449.

GEOLOGY AND GEOGRAPHY

Chairman: WILLIAM D. BROOKS, Department of Geography and Geology
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NEIL V. WEBER, Department of Earth Science
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was elected Chairman for 1976

ABSTRACTS

Socioeconomic Variations of Black Residential Areas in Terre Haute, Indiana. JOHN MCCLAIN, Department of Geography and Geology, Indiana State University, Terre Haute, Indiana, 47809.—Within Terre Haute there are six black residential areas, ranging in size from a high of 409 black households to a low of 29. In analyzing these areas, 24 socioeconomic variables were considered within the following data categories: (1) quality of residences, (2) occupant characteristics, (3) public facilities, (4) economic activities, and, (5) social facilities. *1970 U.S. Census of Housing* statistics and interview data collected according to standard sampling techniques were utilized in the research. Chi square analysis was selected since the scales of measurement and range in area sizes made traditional analysis of variance inappropriate. Tests for significant differences among and between the areas were computed and, when found to be significant, contingency coefficients were derived. With this procedure, significant socioeconomic variations among and between the residential areas were identified and the significant variables rank-ordered on the basis of their contingency coefficients.

Land Use Change and Impacts on Flood Plains. REGINALDO DOS SANTOS and ROBERT D. MILES, School of Civil Engineering, Purdue University, West Lafayette, Indiana 47907.—An analysis of land use change in the Happy Hollow Park watershed and the growth of the delta in the Wabash River was made using aerial photography obtained at 10 different periods of time from 1929 to 1974. The analysis showed that when corrections were made for river stage fluctuations that the delta formed on the west bank of the Wabash River and significantly increased in size as the land use changed from agricultural-forest to residential-forest. The most critical period of delta formation occurred during the period from 1953 to 1968 as the home sites were under construction and large areas of exposed soils were subject to runoff and erosion. The analysis shows that an equivalent area of erosion on the east bank of the Wabash River has also occurred. Attempts to model the changes were not successful. Recent photography shows that the delta may be stabilized as all property has been developed but east bank erosion may increase without protective works.

Land Use Mapping of the Indiana Dunes National Lakeshore. WAYNE E. KIEFER, Department of Geography, Central Michigan University, Mount Pleasant, Michigan 48859.—The land use in and around the Indiana Dunes National Lakeshore was mapped during 1974 as part of

a comprehensive environmental inventory. Land use maps were compiled for 1938 and 1958 from U.S. Department of Agriculture aerial photographs. Seventeen categories of vegetative cover were mapped within the National Lakeshore and the area of each mapped unit was measured. The data provides a comprehensive inventory for the planners at the National Park Service and a base line from which to measure and assess change.

Highway Route Location Utilizing Remote Sensing Techniques, Ft. Wayne, Indiana. S. G. JORDAN and T. R. WEST, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana 47906.—Analysis of remotely sensed data from northeastern Ft. Wayne, Allen County, Indiana, provided evaluations of several route corridors for the Indiana Highway Commission currently planning a dual-lane by-pass around the city. Computer-assisted classification of ERTS imagery (June 8, 1973) was supplemented by the county engineering soils and the agricultural soils maps, plus 9" x 9" aerial photography used as ground-based data.

Relationships among spectral response of soils, soil textural groups and landforms were also investigated. Soils developed on the two landforms, the Lake Maumee Plain and Wisconsin ground moraine, were sufficiently similar that accurate delineation was not possible through spectral response alone and the wavelength bands available from the ERTS satellite.

Classification of the ERTS imagery did contribute positively to the selection of corridors. Detected were poorly drained areas containing a high degree of organic soil which were not indicated on the two surface-materials maps. This allowed for delineation of corridors beyond troublesome areas at an early stage in the planning process.

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Remnant Magnetism of Pleistocene Sediments of Indiana

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Abstract

Remnant magnetism of interglacial and intraglacial silt or clay deposits in Indiana, including samples from within and below so-called Kansan till of western Indiana, from intra-Wisconsinan silts of western Indiana, and from Wisconsinan loesses of southern Indiana, reveals that the materials are normally magnetized. This suggests that the Kansan till that has been defined in several often-visited exposures in western Indiana was deposited after about 700,000 years ago, that is, during the Brunhes Normal Polarity Epoch. No evidence has yet been found for inter-Brunhes reversals, such as the Blake, Laschamp, and Puget Reversed Polarity Events.

Normal polarity characterizes silts within and below numerous exposures of a till in west-central Indiana that is an equivalent of the Hillery Till Member, a unit of Kansan age first described in the Danville area of Illinois. At an exposure on Mill Creek in Fountain County, however, organic silts below Kansan and other as yet uncorrelated tills and above thick, highly weathered alluvium atop Lafayette-like gravel are reversely magnetized, and presumably fall within the Matuyama Reversed Polarity Epoch. Reversed polarity also characterizes the laminated fossiliferous lake clays of the Handley Farm section in Fayette County, eastern Indiana. These clays contain a full interglacial pollen profile that has been interpreted as being Yarmouthian in age by R. O. Kapp and A. M. Gooding. Deposits of western Indiana (silts within and below presumed Kansan till), however, are normally magnetized; thus the supposed Yarmouthian interval of western Indiana is most likely of normal polarity. Therefore the clays of the Handley Farm section and an underlying till are probably older than the so-called Kansan of western Indiana.

Introduction

Purpose and Scope of Study

The dating of glacial deposits in Indiana as throughout the Midwest has been of a very relative nature. The drift below the first paleosol below the youngest deposits, the Wisconsinan, has been considered to be the Illinoian drift. The next drift below has been considered to be the Kansan. Because no one has ever proved a fourth distinct drift in Indiana, the Nebraskan Stage has not been recognized in this state. Such a process of counting downward leaves much to be desired, of course, but until recently little recourse has been available. Studies of the physical characteristics of till units will eventually allow detailed rock-unit correlations of units to be made regionally. A detailed rock stratigraphy has been defined in the Danville, Illinois, area (24, 25), and work in progress (2) has now extended recognition of many of these units into western Indiana and has added additional units to the sequence. Petrographic work on tills has been underway for some time in eastern Indiana. (See 16.) Through such studies some tills in west-central Indiana once thought to be pre-Wisconsinan in age are now known to be Wisconsinan; some thought to be Wisconsinan or Illinoian in age are now known to be at least as old as Kansan. At best, however, such rock-stratigraphic correlations only correlate a unit with one or more significant sections elsewhere where paleosols are in place in the stratigraphic section, and where one still counts downward and calls

the third major drift the Kansan. Thus, an absolute time scale still remains essential to interpretations made from rock stratigraphy.

Carbon-14 dating methods have aided in identifying and correlating Wisconsin deposits younger than about 40,000 years. This timespan is an important, but rather insignificant, part of the few-million-year-old glacial age. Unfortunately, we lack in this part of the Midwest any recognizable volcanic ash units of the sort now recognized in relative abundance in the Plains states, where at least five significant ash falls are recognized (3, 4). Indeed, the basic definitions of Kansan and Nebraskan drifts in their type areas are now being scrutinized in the light of this new information, and the Pleistocene record is now seen to extend much farther back in time than was once recognized (3, 4).

We do have available one method of dating our older glacial deposits in a relatively absolute sense. The method is magnetostratigraphy. The orientation of the earth's magnetic field has flip-flopped through time, the last major shift from a reversed state, in which magnetic vectors pointed southward and up in our hemisphere, to a normal state in which magnetic vectors pointed northward and down in our hemisphere, occurring about 700,000 years ago. This date marks the boundary between the Brunhes Normal Polarity Epoch and the preceding Matuyama Reversed Polarity Epoch. (See 7.) *Detrital remnant magnetism* (DRM), that orientation imparted to certain magnetic grains by the earth's magnetic field at the time of their deposition, is a property measurable in sediments. During the past decade a rather detailed time scale of geomagnetic reversals has been outlined. (See 7, 8, 9.) The time scale for the past 4 million years contains four major epochs when magnetic delineation has been dominantly north (with downward inclination) or south (with upward inclination). Numerous shorter events are known within each epoch.

The Brunhes-Matuyama boundary (0.7 million years B.P.) is within the Pleistocene time interval as already determined in studies of continental and oceanic sediments, and the placement of the older Pleistocene deposits in Indiana with respect to the Matuyama reversed and Brunhes normal epochs provides a simple but useful dating reference. This distinction will allow necessary comparisons to be made between old tills in eastern and western Indiana and comparisons to be made to type deposits to the west.

The recognition of reversed events known or suspected within the Brunhes epoch would be of even more specific value in correlation. Evidence for the Blake Reversed Polarity Event (35, see also 28) would be expected in sediments of Sangamonian age. Evidence for the short-lived Laschamp or Puget Reversed Polarity Events might be expected in middle to late Wisconsinan deposits (see 5, 11), although any such events must have been exceptionally short (10).

A principal purpose of this study was to sample intratill and sub till stratified silt and clay deposits from eastern and western Indiana (Fig. 2) in order to place the deposits with respect to the Brunhes-Matuyama boundary. A second purpose was to sample loesses from southwestern Indiana in order to determine whether they record any of the minor events within the Brunhes Normal Polarity Epoch.

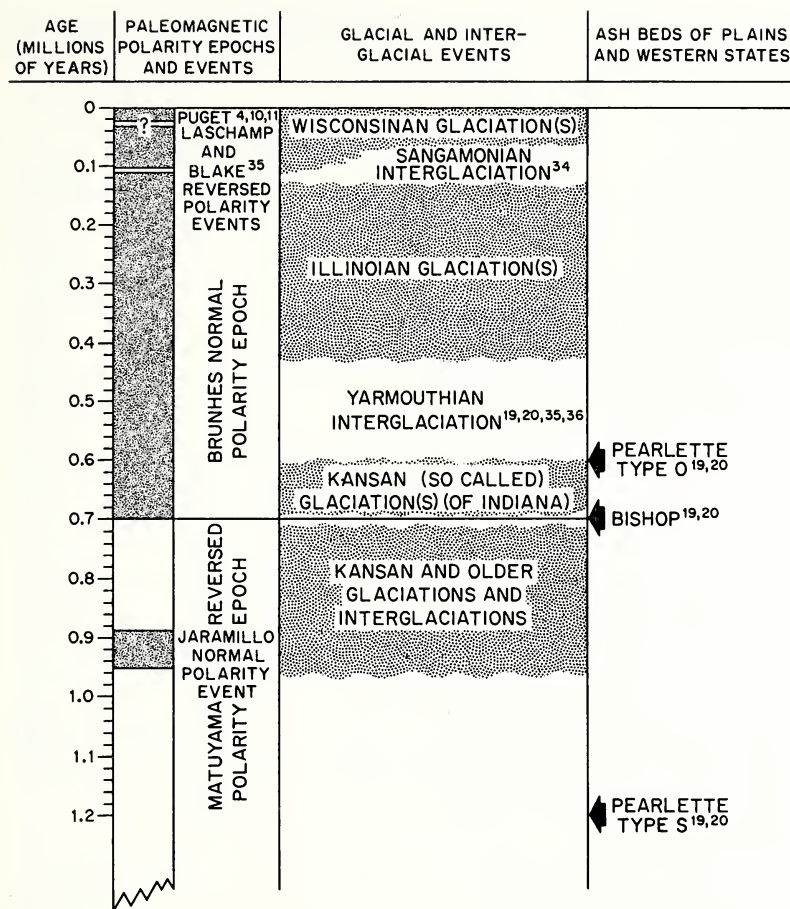


FIGURE 1. Diagram illustrating time scale of geomagnetic polarity events of the last million years, glaciations and interglaciations, and positions of ash beds of the western and plains states. Placement of time lines is somewhat speculative. Superscripts indicate source or discussion references. Placement of the so-called Kansan of Indiana is tentative, at best.

Previous Work

Interest in the use of paleomagnetic data as a regional and world-wide correlation tool was generated by George Kukla (see 27, 28) during his collecting tour of midwestern sections in 1972. His results were presented informally at the American Quaternary Association meetings in Miami, 1972, and at the North-Central Section meeting of the Geological Society of America at Columbia, Missouri, in 1973. Results of magnetic studies in the Danville, Illinois, area (29) indicate reversely magnetized silts beneath Kansan tills but normally magnetized silts between those tills (Tilton and Hillery Till Members of the Banner Formation).

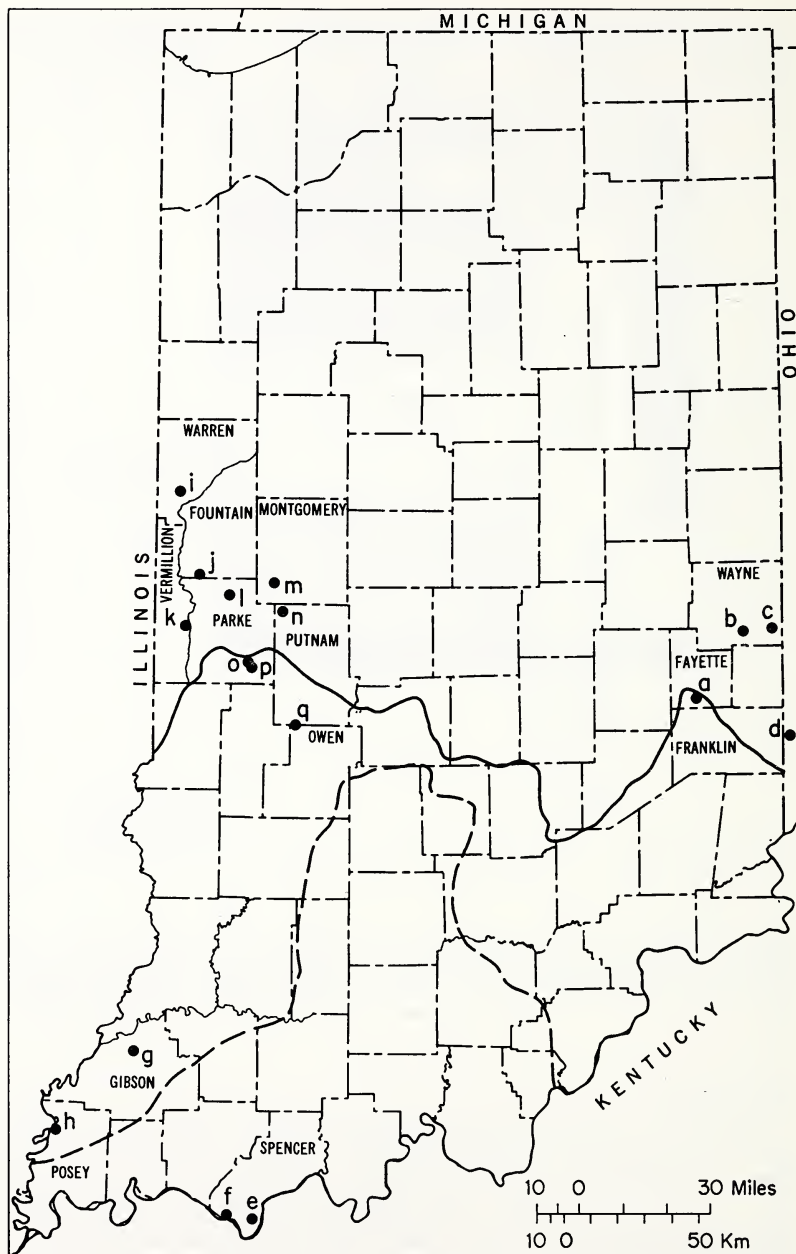


FIGURE 2. Location of sampling sites for studies of paleomagnetism of Pleistocene deposits in Indiana. Boundaries of Wisconsinan and of older glacial deposits shown by solid and dashed lines, respectively.

Hoyer (18) found the Minford Silt of southern Ohio to be reversely magnetized. The silts were deposited within the upper Teays Valley when its lower reaches were first blocked by glacial ice and drift.

Principals

Most rocks or unconsolidated sediments exhibit a measurable *natural remnant magnetism* (NRM) owing to the presence in the material of at least small quantities of certain magnetic mineral grains, most commonly iron oxide minerals. This fossil magnetization, or paleomagnetism, is referred to as *detrital remnant magnetism* where it occurs because of alignment of magnetic mineral grains in a sediment, the alignment reflecting the alignment of the grains parallel to the magnetic lines of force at the time of deposition.

The NRM initially measured in sediments consists of a primary DRM, as just described, in addition to various subsequent or secondary magnetization, most importantly *viscous remnant magnetization* (VRM), a relatively weak, or soft, magnetization imposed by the present field. Such secondary magnetization may be removed by cleaning, or partial alternating field demagnetization, as described below. The acquired VRM in samples of the age studied here can be expected to be destroyed by cleaning in fields of a few hundred oersteds. (See 32.) The measurable magnetic properties of a rock sample are the same as those of today's magnetic field and consist of a declination (a horizontal orientation between 0° and 360°) and an inclination (a vertical angle with respect to the horizontal). In central Indiana the present declination is about $1\frac{1}{2}^\circ$ east of north and the inclination is about 72° downward to the north. The inclination of DRM exhibited by sediment particles is expected to be somewhat less than true inclination at the time of deposition owing to physical grain interactions during deposition.

Methods

Samples were collected from surface exposures of interglacial and intraglacial silt and clay deposits of west-central and east-central Indiana and from loesses of southern Indiana. Original horizontal or nearly horizontal stratification was evident in most sections except those of loess. No evidence of significant deformation was found in any sections sampled. Oriented samples were taken with a block coring device measuring 3 cm x 3 cm x 3 cm and were transferred to plastic cubes in the field. Voids within cubes and tops of cubes were sealed with paraffin, in the field in some instances, to facilitate transfer and laboratory analysis.

Samples were analyzed in a spinner magnetometer having a sensitivity of 10^{-6} cgs. Alternating field (A.F.) demagnetization utilizing a 3-axis tumbler was used to clean samples. Samples were analyzed initially for NRM and for DRM after cleaning in fields of 200 to 400 oersteds. Owing to the diverse nature of the sediments studied, the cleaning fields varied between and within sections. Selected samples were cleaned progressively in fields ranging from 50 to 800 oersteds.

Magnetic vectors were determined for six orientations of the cubes. Vectors averaged for the three axes were plotted stereographically on

an equal area net. Down and north hemisphere projections for samples strong enough to withstand A.F. demagnetization through at least 200 oersteds are presumed herein to record normal polarity; up and south hemisphere projections are presumed to record reversed polarity.

Samples that yielded NRM data and withstood some small amount of A.F. demagnetization, or that yielded somewhat spurious results, are listed as probably normal or probably reversed. Samples that were too weak to yield meaningful initial NRM data are listed as indeterminate in the figures. NRM and DRM intensities listed below are averages for the six orientations measured.

Results

Detrital remnant magnetism of both normal and reversed orientation was found in the Pleistocene sediments of Indiana. Intensities of NRM ranged from 0 to more than 100 cgs units. Variations were high between sections and within sections as a function of grain size, weathering, and genesis. Most samples followed relatively smooth A.F. demagnetization curves (Fig. 3) and most were considered stable through cleaning of 400 oersteds; a few samples, however, became unstable after cleaning in as few as 200 oersteds. In general, roughly one-third to one-half of the NRM was removed upon cleaning at 200 oersteds (Fig. 3).

Eastern Indiana

Handley Farm section (NW cor., SE $\frac{1}{4}$ sec. 28, T. 13 N., R. 12 E., Fayette County; Fig. 2a): Units are, in descending order, loess, till of apparent Illinoian age, pro-Illinoian outwash and basal clay, weathered till (variably interpreted as Kansan till or Yarmouthian colluvium), calcareous clay containing a full interglacial pollen sequence, till, and Ordovician limestone.

The main clay section at Handley Farm, that containing a full interglacial pollen profile and that most recently interpreted as of Yarmouthian age (unit 4 of 26), definitely has reversed DRM (Fig. 4). Some samples in the top part of the clay section retain only very weak remnant magnetic properties (Fig. 4), apparently owing to weathering associated with the paleosol atop the thin till directly overlying the clay. Some samples at various lower levels are similarly weak and have nondeterminable or only barely determinable magnetic vectors. Some of these yield definitely southward (reversed) declination but anomalous positive (downward, normal) inclination. The latter are very probably reversed but basically too weak to allow total cleaning of the normal effects of VRM. One stronger sample of initially similar south-down orientation did clean at 200 oersteds to an unquestionably reversed orientation.

Four of five samples of the calcareous clay overlying the weathered till and main clay (unit 7 of 26) yielded no results. This is attributed to the poor condition, the apparently modern root-disturbed nature of the available exposure. One sample yielded possibly normal DRM vectors, but sufficient cleaning was impossible.

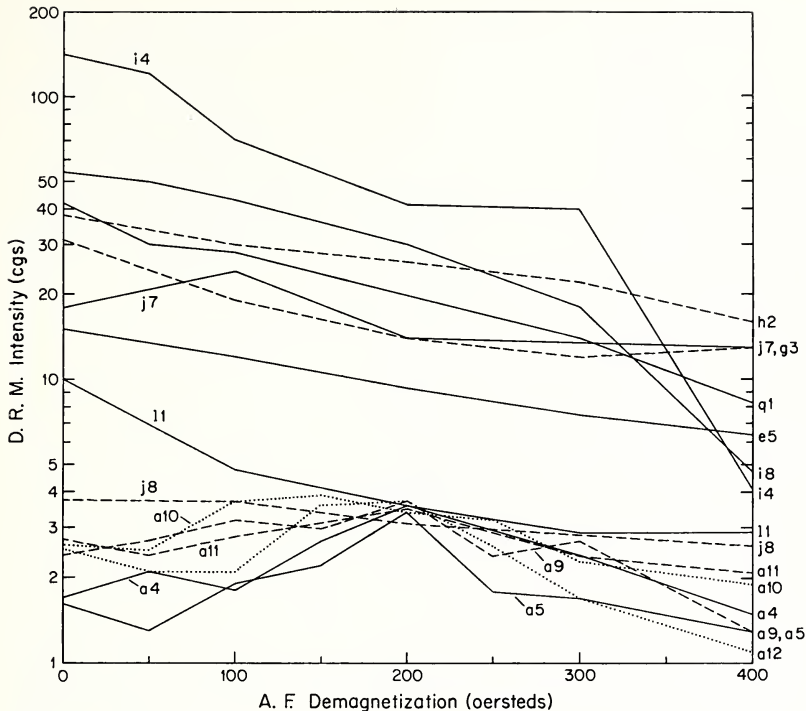


FIGURE 3. Variation of detrital remnant magnetism intensity with stages of alternating field demagnetization of representative strong samples of interglacial and intraglacial silts and clays of west-central Indiana, loesses of southern Indiana, and the Handley Farm section of eastern Indiana. All samples are normal, except those from sections a and j, which are reversed. Samples numbered from top down in referenced figures: a, main clay, Handley Farm section (fig. 4a); e, loess, section 2 of Ray (33) (fig. 5e); g, loess, Patoka section (fig. 5g); h, loess, New Harmony section (fig. 5h); i, silt, Redwood Creek section (fig. 6i); j, silt, Mill Creek section (fig. 6j); l, silt, Lusk Chapel section (fig. 6l); m, silt, Liberty School section (fig. 6m); q, silt, Cagles Mill section (fig. 6q).

Alternating field demagnetization curves (Fig. 3) for the samples from the main clay at Handley Farm are markedly different from those obtained for most other samples. Remnant magnetic intensity is actually increased in almost all samples with demagnetization to 200 oersteds, apparently reflecting the subtraction of the normal viscous remnant magnetic vector component, that component imposed upon the sediment by the field of the past 0.7 million years.

Kapp and Gooding (26) reported the presence of a till unit beneath the clays. If a till is, indeed, present in this position, it is older than the so-called Kansan till and Yarmouthian soil of western Indiana (considering the paleomagnetic data presented below that show the interglacial clays to be pre-Yarmouthian).

During a short visit to the site in October, 1975, with H. H. Gray and J. Bassett, an auger hole was drilled to bedrock beneath the central part of the exposure. No obvious till was encountered in this hole.

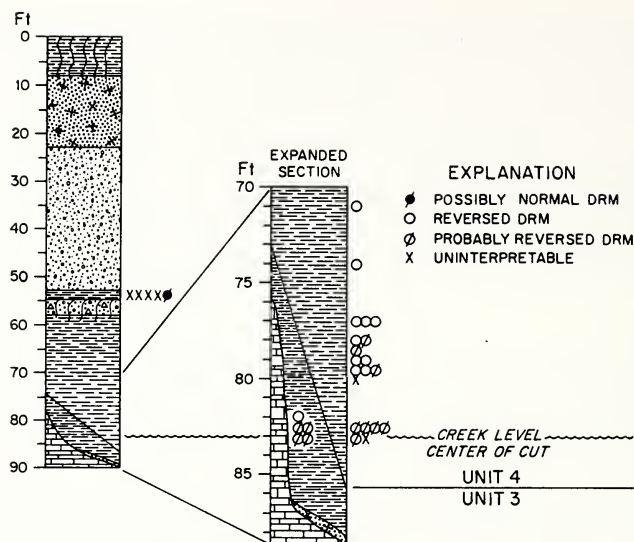


FIGURE 4. Detrital remnant magnetism determined for clays of the Handley Farm section (15, 26), southeastern Indiana; NW cor., SE $\frac{1}{4}$ sec. 28, T. 13, N., R. 12 E.; (fig. 2a).

Rather, the lake clays grade downward into a sandy basal zone rich in local shale granules. Heavy mineral analysis of this basal material yielded small quantities of fine and very fine sand-sized heavies, mostly tourmaline, zircon, and garnet, a seemingly nonglacial assemblage. The overlying clay, however, contains a relatively high percentage of amphiboles, including a few large fresh hornblende grains, although only about 20 grains were obtained from a 300-grain sample (John Bassett, personal communication). These fresh grains may indicate a till source nearby, stratigraphically below the interglacial clay deposit. Kapp and Gooding (26) reported some pollen evidence of colder climate in the basal clay. Intraglacial stratified deposits have been described within till considered to be of Kansan age in eastern Indiana; however, the exposures are no longer available.

Unit sampled	DRM Orientation	NRM Intensity
Unit 7 of Kapp and Gooding (26), clay above paleosol in colluvium	Normal? (1 of 5 samples)	0-1.4 cgs
Units 4 and 3 of Kapp and Gooding (26), main clays	Reversed (10 of 25 samples)	0-2.7 cgs

All other units sampled in eastern Indiana are of intra-Wisconsinan silts. These were not sampled in detail, and most relate to sections recently described by Gooding (17).

Darrah Farm section (14, 13) (not diagrammed; SE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 5, T. 15 N., R. 14 E., Wayne County; fig. 2b):

<u>Unit sampled</u>	<u>DRM Orientation</u>	<u>NRM Intensity</u>
Unit 15 of Gooding (14, fig. 2), unit 12 of Gamble (13, fig. 5), silt between Wisconsinan tills	Normal (1 sample)	27 cgs

Forest Hills Country Club section (17) (not diagrammed; NW¼ sec. 15, T. 13 N., R. 1 W., Wayne County; fig 2c):

<u>Unit sampled</u>	<u>DRM Orientation</u>	<u>NRM Intensity</u>
Intratill silt presumed to mark position of Sidney Interstadial of Gooding (17, p. 1000-1009)	Normal (2 samples)	11 cgs

New Paris, Ohio, Waterworks section (17) (not diagrammed; SW cor., sec. 21, T. 9 N., R. 1 E., Preble County, Ohio; fig. 2d):

<u>Unit sampled</u>	<u>DRM Orientation</u>	<u>NRM Intensity</u>
Soil of Sidney Interstadial of Gooding (17, p. 1000- 1009)	Normal (2 samples)	17-28 cgs
Silt of New Paris Inter- stadial of Gooding (17, p. 994-1000)	Normal (2 samples)	6.1-6.8 cgs

Southern Indiana

The loess members of the Atherton Formation of southern Indiana are normally magnetized. Samples were taken from sections in Gibson, Posey, and Spencer Counties in southern Indiana (fig. 2, e-h) containing loess units identified by Ray (33) as the Peoria, Farmdale (=Roxana Silt of Illinois), and Loveland or the Peoria overlying undifferentiated loess (21, probably Roxana equivalent) (fig. 5). The sections sampled were: e, section 2 of Ray (33, p. 66), NW¼SW¼ sec. 9, T. 8 S., R. 6 W.; f, section 7 of Ray (33, p. 61), NW¼SW¼ sec. 4, T. 8 S., R. 7 W.; g, Patoka section of Johnson (21, p. 195-196), center of SE¼ sec. 26, T. 1 S., R. 11 W.; h, New Harmony section of Johnson (21, p. 201-202; see also 12, p. 29, and 31, pl. 2A), NW¼SW¼ sec. 1, T. 5 S., R. 14 W.

<u>Unit sampled</u>	<u>DRM Orientation</u>	<u>NRM Intensity</u>
Peoria Loess Member (4 sections)	Normal (8 of 9 samples)	0-47 cgs
Farmdale Loess Member (4 sections)	Normal (8 of 9 samples)	0-32 cgs
Loveland Loess Member (1 section)	Normal (1 sample)	30 cgs

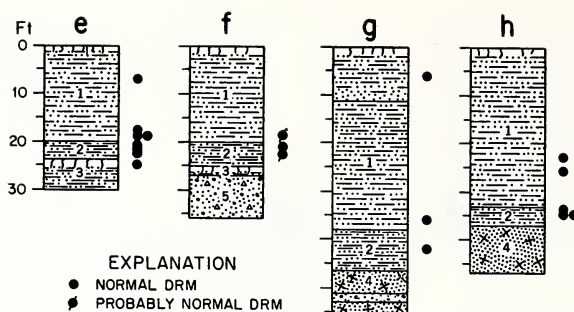


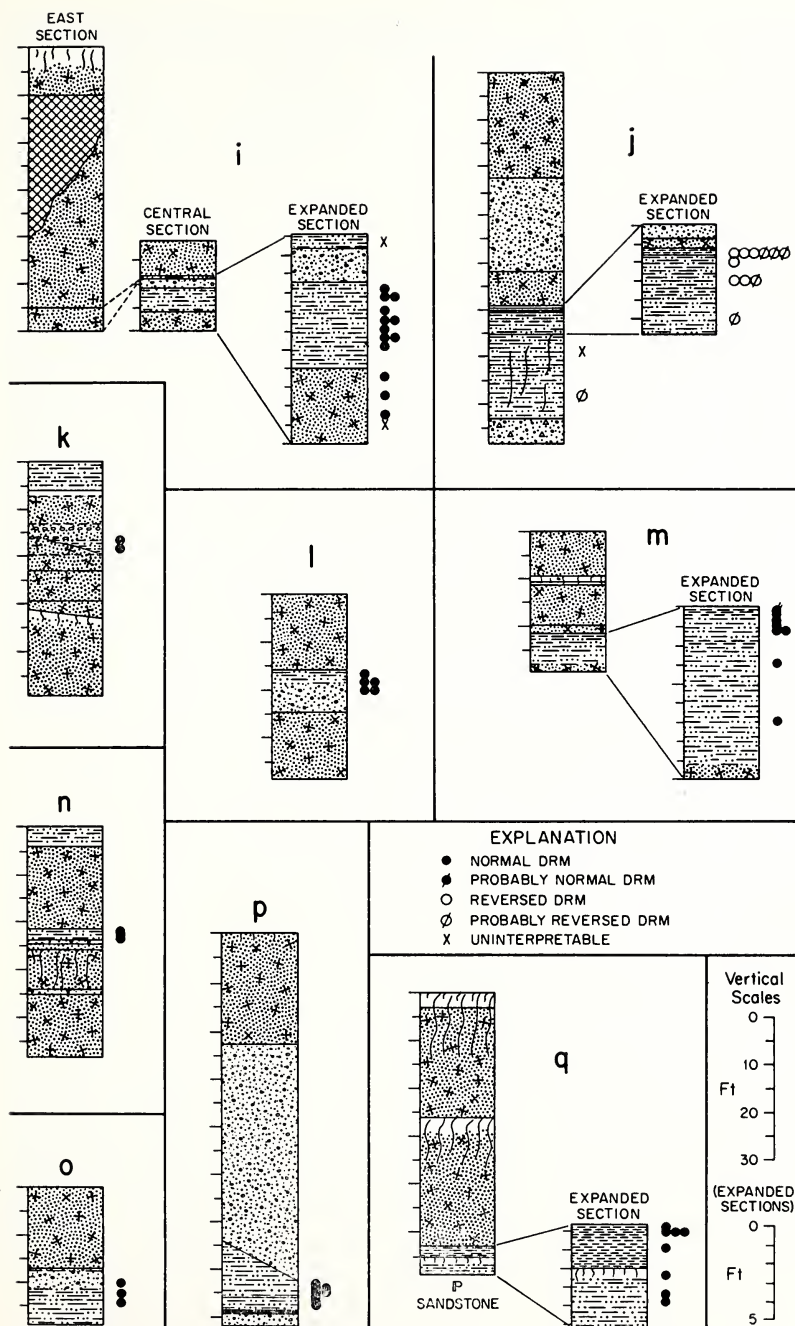
FIGURE 5. Detrital remnant magnetism determined for loesses of the Atherton Formation of southern Indiana. In descending order the units are (1) Peoria Loess Member, (2) Farmdale Loess Member (=Roxana Silt of Illinois), (3) Loveland Loess Member, (4) till of Illinoian or greater age, or (5) Luce Gravel of Ray (33). Section locations (see fig. 2): e, section 2 of Ray (33); f, section 7 of Ray (33, p. 61); g, Patoka section of Johnson (21, p. 195-196); h, New Harmony section of Johnson (21, p. 201-202).

West-central Indiana

Redwood Creek section (SE $\frac{1}{4}$ NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 27, T. 21 N., R. 9 W., Warren County, on south cutbank of eastward-flowing tributary to Redwood Creek): Section diagrammed is composite of low section containing silt beds and larger multiple till section downstream (east) (fig. 2i). Several tills, including equivalents of the Tilton and (or) Hillery Till Members (Banner Formation) of the Danville, Illinois, area, and a basal, peculiarly red and clayey till possibly equivalent to the Harmattan Till Member of the Banner Formation of that same area, overlie silt containing organic debris and snails, which in turn overlies gleyed till-colluvial material (fig. 6i). The lower material is noncalcareous and contains some evidence of subaerial weathering. The lowest material is most probably a correlative of the Hegeler Till Member (Banner Formation) in Illinois (22). It contains a distinctly glacial heavy mineral suite, which has characteristics of a Lake Michigan Lobe source (low garnet-epidote ratio). The silt and material below are normally magnetized.

The normal polarity of these materials is somewhat problematical. Silts thought to be stratigraphically above the Hegeler Till Member at Danville are reversed. (See 23, 29.) Additional rock-stratigraphic study is needed to resolve this inconsistency. Pollen and snail analyses (to interpret inter glacial vs. intraglacial magnitude) of the silt at

FIGURE 6. Detrital remnant magnetism determined for inter- and intra-glacial silts and clays in sections in west-central Indiana. Section locations (see fig. 2): i, Redwood Creek section; j, Mill Creek section; k, Hillsdale section; l, Lusk Chapel section; m, Liberty School section; n, Russellville Quarry section; o, West Mansfield section; p, Raccoon Creek section; q, Cagles Mill section.



Redwood Creek would be useful in defining the time lapsed between deposition of the probable Hegeler till and the overlying tills.

<u>Unit sampled</u>	<u>DRM Orientation</u>	<u>NRM Intensity</u>
Silt over sand over main silt	? (1 sample)	3.2± cgs
Main silt	Normal (10 samples)	2.2-136 cgs
Lower till-like material (Hegeler till?)	Normal (3 of 4 samples)	2.6-4.4 cgs

Mill Creek section (NW¼NW¼SE¼ sec. 32, T. 18 N., R. 8 W., Fountain County, cutbank on south side of Mill Creek; fig. 2j): Several tills, as yet not studied in detail, overlie a thin sticky clay which in turn overlies a massive silt containing snails, oxidized in its upper half, and organic matter in the topmost part. This overlies thick highly weathered silty clay which in turn overlies brown Lafayette-like chert gravel (fig. 6j). (One or more of the overlying tills is very probably Kansan in age.) The clay, silt, and underlying weathered unit all are reversely magnetized.

Unfortunately, knowledge of the position of the magnetically reversed silt beneath tills and above deeply weathered alluvium of possible Tertiary age has no immediate usefulness. Pollen and snail studies of this silt, however, could add much useful information. The presence, for instance, of a fauna or a flora indicative of a cool climate would relate the reversely magnetized silt to a preceding glaciation or would relate it closely in time to the overlying till, most likely the latter.

<u>Unit sampled</u>	<u>DRM Orientation</u>	<u>NRM Intensity</u>
Clay overlying silt	Reversed (3 of 6 samples)	0-4.8 cgs
Organic silt	Reversed (3 of 5 samples)	1.4-7.7 cgs
Weathered silty clay	Reversed? (1 of 2 samples)	0-1.3 cgs

Hillsdale section (SE¼SW¼NE¼ sec. 34, T. 16 N., R. 9 W., Vermillion County, borrow pit north of U.S. Highway 36; fig. 2k): Thin loess and a possible thin cap of loam till of the Wedron Formation overlie a thick sequence of pinkish loam tills, separated by or including numerous stone lines. A thin organic and snail-rich silt occurs within the pinkish tills, which are probably equivalent of Hillery till of eastern Illinois. The till overlies a thin greenish clayey till, possibly an equivalent of Harmattan till of eastern Illinois (24), which in turn here overlies a till containing an apparent truncated paleosol, indicated by oxidation and marked nodular and vein-fill carbonate deposition (fig. 6k). The organic silt is normally magnetized.

<u>Unit sampled</u>	<u>DRM Orientation</u>	<u>NRM Intensity</u>
Silt within till	Normal (2 samples)	22-23 cgs

Lusk Chapel section ($SE\frac{1}{4}NW\frac{1}{4}NW\frac{1}{4}$ sec. 22, T. 17 N., R. 7 W., Parke County, lower of two road cut sections, southwest side of 50 East Road, at north boundary of Turkey Run State Park; (fig. 21): A calcareous silt and sand unit is present within a faintly pink-tinged loam till (fig. 61) in two road cut exposures. The till is probably equivalent to the Hillery till (Kansan) of eastern Illinois (24). The silt is magnetically normal.

Unit sampled	DRM Orientation	NRM Intensity
Silt bed within till	Normal (5 samples)	8.3-10 cgs

Liberty School section (SW cor., sec. 5, T. 17 N., R. 5 W., Montgomery County, stream-cut bank; fig. 2m): The Liberty School section (fig. 6m) has been interpreted as containing Wisconsinan and Illinoian tills, Yarmouthian organic-rich stratified noncalcareous alluvium, and a basal till (40, p. 33-34). I do not believe that the basal material in this section is a till, which is not to say that a till may not occur stratigraphically below. Johnson and others (24) have suggested on the basis of physical properties that the reddish till considered to be Illinoian by Wayne is, rather, the equivalent of Hillery till (Kansan) of eastern Illinois. I agree with this correlation. Thus, the basal silts and clays at Liberty School, which are normally magnetized, are probably intra- or pre-Kansan in age.

Unit sampled	DRM Orientation	NRM Intensity
Stratified silt and clay, basal 8+ feet of section	Normal (6 of 8 samples)	1.5-34 cgs

Russellville Quarry section ($SE\frac{1}{4}SE\frac{1}{4}NW\frac{1}{4}$ sec. 8, T. 16 N., R. 5 W., Putnam County, west wall of quarry; fig. 2n): The surface till of the Trafalgar Formation overlies an organic and snail-rich silt dating $21,000 \pm 200$ radiocarbon years B.P. (ISGS-387). Beneath are additional tills and a paleosol (fig. 6n). The silt is normally magnetized.

Unit sampled	DRM Orientation	NRM Intensity
Silt beneath surface till	Normal (3 samples)	11-16 cgs

West Mansfield section ($NE\frac{1}{4}SE\frac{1}{4}NE\frac{1}{4}$ sec. 7, T. 14 N., R. 6 W., Parke County, borrow pit exposure on north side of county road; fig. 2o): A loam till overlies 10 to 15 feet of interstratified sand and silt (fig. 6o). The till has not been studied in detail, but it probably is the equivalent of the Butlerville Till Member (Illinoian) of the Jessup Formation at the Cagles Mill section in Putnam County. The silt is normally magnetized.

Unit sampled	DRM Orientation	NRM Intensity
Silt units beneath till	Normal (3 samples)	3.6-17 cgs

Raccoon Creek section ($NE\frac{1}{4}SW\frac{1}{4}NW\frac{1}{4}$ sec. 18, T. 14 N. R. 6 W., Parke County, cutbank on south side of Big Raccoon Creek; fig. 2p):

This section on Raccoon Creek west of Mansfield was used by Wayne (39, p. 75) as a reference section for the Jessup and Atherton Formations. A single till, considered to be the Butlerville of Illinoian age, overlies gravel, sand, silt, and a highly compacted basal peat (braunkohle of Wayne (39) (fig. 6p), the latter considered to be of Yarmouthian age. No criterion exists, other than its occurrence as a surface till in an area supposedly underlain by Illinoian till, to assign an Illinoian age to the till or a Yarmouthian age to the lowest sediment. No rock-stratigraphic work has been done in this area. The silt is normally magnetized.

<u>Unit sampled</u>	<u>DRM Orientation</u>	<u>NRM Intensity</u>
Gray finely laminated silt and clay	Normal (8 samples)	1.9-23 cgs
Dark stratified silt immediately overlying highly compacted peat	Normal (2 samples)	23-24 cgs

Cagles Mill section (Cataract Lake spillway, SE $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 13, T. 12 N., R. 5 W., Putnam County, section at east end of north side of spillway cut; fig. 2q): The Cagle Loess Member of the Atherton Formation, a massive silt containing snails and organic material in its top part, immediately underlies a thin clay, two distinct tills, and two major paleosols (fig. 6q). The tills have been interpreted as Illinoian and Kansan in age (38, 39, 40). The Cagles Mill section was one of several in the Midwest sampled by George Kukla in 1972. Results of his sampling, as presented informally in Columbia, Missouri, in 1973, showed the unit to have normal DRM. His finding has been verified in this study (fig. 6q). Rock-stratigraphic work has not yet allowed the tills of this section to be compared with other tills in western Indiana.

<u>Unit sampled</u>	<u>DRM Orientation</u>	<u>NRM Intensity</u>
Stratified clay atop Cagle Loess Member	Normal (5 samples)	13-41 cgs
Cagle Loess Member	Normal (3 samples)	10-14 cgs

Conclusions

The reversely magnetized main clay unit of the Handley Farm section of eastern Indiana is probably older than most of the presumed Kansan tills of western Indiana and eastern Illinois. Therefore, it is not likely of Yarmouthian age (at least as that age has been defined for western Indiana) as interpreted by Kapp and Gooding (26); rather, it is much older. Although the Brunhes Normal Polarity Epoch is known to contain several relatively short reversed events in its latter part (fig. 1) (which postdate deposition of any of the sediments in the Handley Farm section), and although additional reversed events may well be found in the future, Cox (8, p. 100) has shown statistically that "a stratigrapher will incur at most a 4-percent risk of being wrong if he concludes that a reversely magnetized deposit has an age greater than 0.7 million years."

The thin weathered till immediately overlying the clays at Handley Farm is probably the equivalent of one of the several tills of Kansan age already described in eastern Indiana (15). Gooding (15) originally interpreted this material as a Kansan till, but later (26) he interpreted it as a late Yarmouthian colluvial deposit. The weathering extending through the till and into the underlying clay could, indeed, represent Yarmouthian weathering as Kapp and Gooding noted (26, p. 231). The presence of a till beneath the lake clays is presently very questionable in my mind—and of very great importance. If a till is, indeed, present beneath the magnetically reversed clays, it would be the oldest till known in Indiana. Classically, it would have to be termed Nebraskan; however, considering the present state of uncertainty as to the identity of the type Kansan and Nebraskan and the recent revelations of the presence of many old type drifts (3, 4) I can only conclude that it is older than the Yarmouthian paleosol and so-called Kansan drift of western Indiana. If the main clay deposit is truly preglacial (for this area), in its own tributary to the preglacial Kentucky River (a northward-flowing tributary to the Teays (37)), then it might be a correlative of the Minford Silt of southern Ohio. The Minford Silt, an upstream backwater deposit formed when the trunk valley of the Teays was first blocked, is reversely magnetized (18).

Spot samples of the Peoria and Farmdale Loess Members of southern Indiana are all normally magnetized; no evidence of a reversed event was found. The Farmdale loess is relatively thin in Indiana sections, and neither it nor the Peoria was sampled continuously or in sufficient detail. Magnetic studies of thick type sections in Illinois might be profitable, however.

Conclusions regarding other sections in eastern and western Indiana must be considered very tentative at this time. Many of the sections reported here were not sampled in sufficient detail. More continuous sampling through the glacial section in the Midwest and some definitive analysis of the type Kansan and Nebraskan deposits in the Plains are necessary. (See 3, 4.) The normal polarity associated with so-called Kansan deposits here most likely records deposition after about 0.7 million years ago during the Brunhes Normal Polarity Epoch rather than during a normal event within the earlier Matuyama Reversed Polarity Epoch. This is supported by the lack thus far of any evidence of a reversed polarity period stratigraphically above these magnetically normal so-called Kansan sediments and by normal polarity associated with the youngest, but not necessarily the older of the so-called Kansan deposits of the Plains (John Boellstorff, personal communication regarding unpublished work by George Kukla).

The normal polarity associated with the so-called Kansan drift of western Indiana is wholly expectable in light of Kukla's original unpublished work and that of Kukla et al. (29).

If the dating of uppermost Kansan and Yarmouthian deposits in the Plains states given by 0.6-million-year-old type O Pearlette ash (see discussion in 6, p. 216) is assumed for the Midwest as well, Kansan time, as we know it in the Midwest, represents a rather miniscule part of the Pleistocene Epoch, although that time span is no more miniscule

than that of the Wisconsinan Age (fig. 1). It is unlikely that such tills as the Cedar Ridge Till of the Wind River Mountains, which occur *below* the 0.7 million-year-old Bishop Ash Bed (1, 34), or tills called Kansan in the Plains that are as old as 1.2 million years can be correlative with so-called Kansan till of our part of the Midwest.

The Cromerian interglacial stage of northern Europe reportedly contains the Brunhes-Matuyama 0.7-my boundary. (See discussion in 6.) A similar major interglacial episode might exist in North America, and various correlations (6, table 3; 3, 4) that place the Yarmouthian Age as spanning a large interval of time centered on that same 0.7-my boundary are certainly logical. However, the relationship may well be more complicated than this, and the probable 0.7-million-year-old so-called Kansan of the Midwest could be equivalent to only a very late portion of what has been called the Kansan or even the Yarmouthian elsewhere, or perhaps it could be equivalent even to what has been called Illinoian in places. Certainly the understanding is confused at this point.

A gross framework of the magnetostratigraphy of Indiana's glacial deposits has been provided herein, into which new examples of old drift deposits may be fitted. However, considering the incomplete sampling of many of the units reported herein, the absence of available and known correlative parallel sections to sample, and the overall lack of suitable consistency checks (see discussion in 30), the conclusions reached herein are at best tentative. Even so, I suggest that magnetostratigraphy combined with detailed petrographic study of tills is the only means of defining the glacial stratigraphic succession in this area. Past regional and trans-Atlantic correlations of glacial and interglacial stages are of questionable validity, and no firm basis for correlation will exist until further stratigraphic, ash-dating, and magnetic work is done in the Plains states and elsewhere.

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Near Neighbor Analysis of the Silurian (Niagaran) Bioherms Near Lagro, Indiana

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Abstract

Spatial relationships among seventeen Silurian (Niagaran) bioherms were analyzed using the near-neighbor statistic. The ratio R between the observed mean distance to the expected mean distance was computed and compared to a random distribution having the same population density. A two-tailed test of significance revealed that the Lagro bioherms exhibit a pattern which is more uniform than random. The majority of the bioherms appear to be distributed in such a way as to maximize their potential for success.

Introduction

Students of Silurian bioherms of northeastern Indiana are continually faced with problems of insufficient surface exposure, limited sub-surface data, and a qualitative view of the Niagaran paleosynecology. Although regional and local paleoenvironmental relationships have been noted frequently, there still exists a need to examine the bioherms with a view toward deriving a quantitative statement which describes their areal variation. Several techniques widely used in other disciplines may contribute to a better understanding of the nature of these mound-like features.

One of these techniques—near-neighbor analysis—was used in this study in order to 1) focus attention on the applicability of the nearest-neighbor statistic to paleobiogeographical investigations, 2) add a new dimension—that of spatial relationships—to the overall study of bioherms; and 3) give workers an added perspective on problems of biohermal paleosynecology. This paper like its predecessor (11) presents the quantitative results of some empirical characteristics of the distribution of bioherms in the Wabash Valley near Lagro, Indiana.

Method

Distance to nearest neighbor as an estimate of the spatial relationships in populations and among communities has been widely used by ecologists, geographers, and biometricians. The spacing of individuals in a community and the spacing of communities themselves is of profound ecological significance. According to Clark and Evans (1), "The pattern of distribution of a population of plants or of animals is a fundamental characteristic of that population, but it is a feature that is extremely difficult to describe in precise and meaningful terms."

In the past, the pattern of distribution of communities or of individuals making up a population has been deduced from the number of individuals per area or the number of communities in a region. Generally no analysis was made of the linear distances separating data points within the area. King (4) noted that these attempts are

open to criticism for their generality and for the fact that they are frequently insensitive to important variations in spatial pattern. Moreover, qualitative terms such as "sparse", "dispersed" or "dense" that have been applied to spatial distribution fosters ambiguity. King suggests that actual measurements be used in the analysis of spatial variation. Nevertheless, it is difficult to decide which of the actually measurable differences are due to genuine ecologic forces and which are due to genetic origin or chance geographic factors (8). Many biosociological concepts of earlier workers were founded upon the assumption that real populations are distributed randomly in nature. Today, this idea is tenable only for testing hypotheses against a presumed random distribution. A random distribution is defined as a set of data points in an area for which any point may have the same chance of occurring anywhere in the area as any other point without mutual interference. The assumption of a statistically random distribution is founded upon contemporary probability theory (10).

As suggested by the name, near-neighbor analysis is the linear measurement of the distance separating an object and its nearest neighbor in space, regardless of direction (Table 1). Distances between all subjects in the population may be measured (as in the present

TABLE 1. *Symbols and definitions employed in a measure of spacing based on the mean distance between nearest neighbors (1).*

N	the number of measurements of distance taken in the observed population or sample. When a single sector is employed, N is also equal to the number of individuals used as centers of measurement.
r	the distance in any specified units from a given individual to its nearest neighbor.
ρ	the density of the observed distribution expressed as the number of individuals per unit of area. (The unit of measurement used in the calculation of ρ must be the same as that used in measuring r.)
Σr	the summation of the measurements of distance to nearest neighbor
$\bar{r}_e = \frac{\Sigma r}{N}$	the mean of the series of distances to nearest neighbor.
$\bar{r}_e = \frac{1}{2\sqrt{\rho}}$	the mean distance to nearest neighbor expected in an infinitely large random distribution of density ρ .
$R = \frac{\bar{r}_a}{\bar{r}_e}$	the measure of the degree to which the observed distribution departs from random expectation with respect to the distance to nearest neighbor.
$c = \frac{\bar{r}_a - \bar{r}_e}{\sigma_{\bar{r}_e}}$	the standard variate of the normal curve.
$\sigma = \frac{0.26136}{\bar{r}_e \sqrt{N\rho}}$	the standard error of the mean distance to nearest neighbor in a randomly distributed population of density ρ .

investigation) or a random sample may be chosen. The actual or observed mean distance ($\bar{r}_a$) is computed together with mean distance which would be expected ($\bar{r}_e$) in an infinitely large random distribution having the same density (ρ). The ratio (R) of the observed mean distance to the expected mean distance is termed the near-neighbor statistic and is a measure of the degree to which the observed distribution approaches or departs from random expectation.

The value R has a limited range. In a totally random distribution $R = 1.0$. If the points are agglomerated and therefore all occupy the same locus, the ratio would obviously be equal to 0.0. In a distribution in which spacing of data points is maximized, $R = 2.1491$. Such a perfectly uniform distribution will exhibit data points distributed in a hexagonal pattern about the center of observation, as shown in Figure 1. Thus, the statistic R provides an expression of the two-dimensional spatial pattern of points within a given area. One might expect that an agglomerated pattern of distribution ($R < 1.0$) may indicate particularly favorable locations and local environments for biotic success. A more uniform distribution ($R = 2.15$) may occur where there is a tendency for competition and where the habitat displays considerable heterogeneity (2.7).

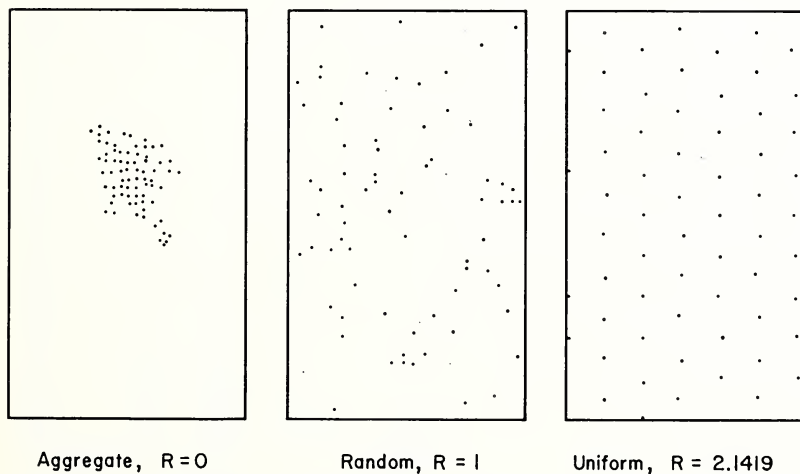


FIGURE 1. *Theoretical patterns of distribution (4).*

Several tests of significance of the departure of the ratio R from a random distribution may be utilized. The method used here was to compute the standard variate of the normal curve (c) using the standard error of the mean. A comparison of the c -value obtained with a table of the normal distribution may establish the significance of the departure under different levels of probability. C -values of 1.96 and 2.58 are significant at the 0.05 and 0.01 levels respectively.

Application

The Wabash River Valley near Lagro, Indiana, with its excellent klintar, was selected as the study area. This area (22.06 km²) is depicted entirely on the Lagro 7.5' topographic quadrangle. The right and left margins of the map serve as the east and west boundaries of the study area. The lower slope break between flood plain and right- and left-hand bluffs marks the southern and northern edges (Fig. 2). Locations of 17 identifiable bioherms were plotted on the map and the

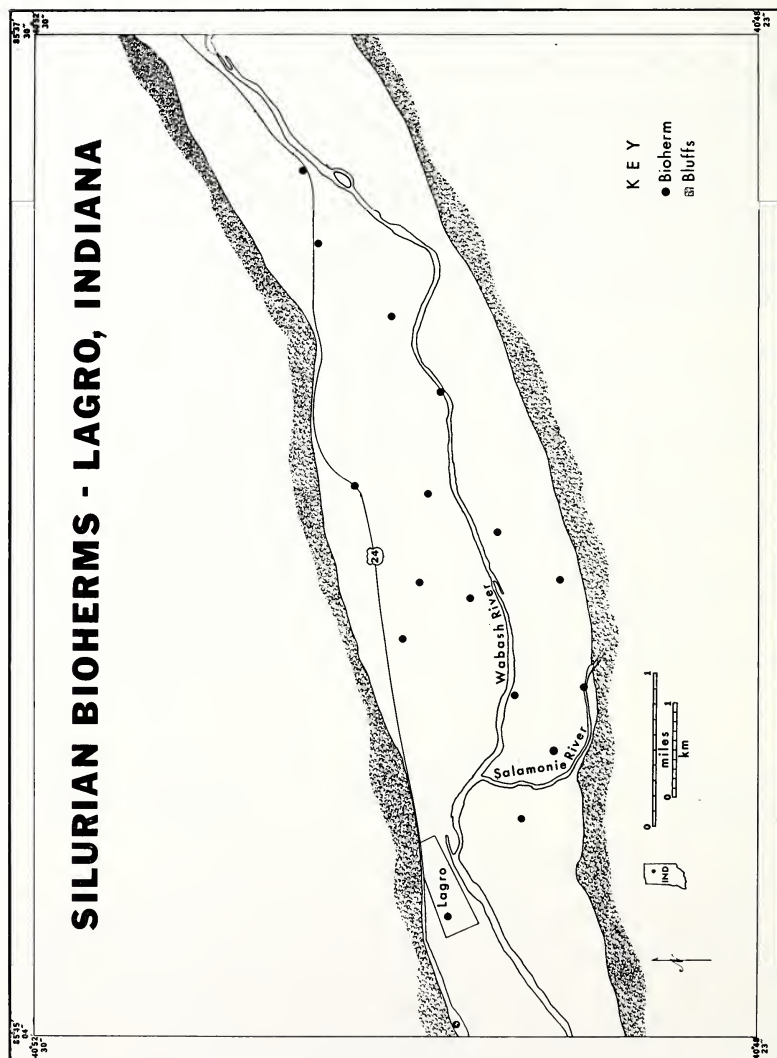


FIGURE 2. *Silurian bioherms—Lagro, Indiana.*

linear distance between the center of each bioherm to its nearest neighbor was measured. Statistics computed are listed in Table 2.

The R-value of 1.46 is significantly greater than 0.0 at the one percent level of significance since $c = 3.69$. This indicates that bioherms in the Lagro area exhibit a tendency to be distributed in a pattern which is more uniform than random. The near-neighbor statistic (R) shows that the observed mean distance ($\bar{r}_a$) is 1.46 times as great as the expected mean distance ($\bar{r}_e$) in a random distribution of the same density.

TABLE 2. Summary of near-neighbor statistics: Lagro, Indiana bioherms.

Number of measurements (N) -----	17
Actual mean distance ($\bar{r}_a$) -----	0.83 Km
Expected mean distance ($\bar{r}_e$) -----	0.56 Km
Area -----	22.06 Km ²
Density (ρ) -----	0.77
Near-neighbor statistic (R) -----	1.46
Standard error of mean ($\sigma_{\bar{r}_e}$) -----	0.72
Standard variate of normal curve (c) -----	3.69

Discussion

Several speculative possibilities may be offered to account for the spatial arrangement of the Lagro bioherms. It is well known among ecologists and geographers studying contemporary biotic and cultural distributions that a regular pattern would be expected in areas of high competition. Both species and communities tend to arrange themselves in order to maximize their potential for success. If one assumes that biohermal communities can "sense" one another's presence (in terms of the effects of food, energy and space; R. L. Anstey, personal communication, 1975), then the spacing of the Lagro bioherms would be expected to be more uniform than random or clustered. On the other hand, the upward and laterally expanding asymmetrical growth (9) may indicate a trend toward coalescence. Thus, although the mathematical trend (R-value) may be in the "direction" of uniform spacing, the growth pattern may have been toward aggregation, if one ignores competition.

Clearly, more work needs to be done on the evolution and distribution of these communities; more bioherms need to be located. A predictive model, perhaps one based upon other known distributions, should be sought in an attempt to help locate buried bioherms. Other unanswered questions include the effects of size (area) occupied by the features, and whether or not there is an hierarchy of sizes of bioherms. Spatial measurements should be taken with regard to an isochronous plane, not merely the exposed "tops", as was done here. Moreover a population model within a fossil community could be derived using nearest neighbor techniques.

Acknowledgements

The writers wish to acknowledge the assistance of Mr. C. H. Ault of the Indiana Geological Survey who provided a list of bioherm locations in the Lagro area. Further thanks are due to Drs. R. L. Anstey, D. K. Chowdhury, and B.-D. Erdtmann and Mr. R. Gertman for their stimulating discussions.

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HISTORY OF SCIENCE

Chairman: J. BENNETT OLSON, Department of Biological Sciences,
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ABSTRACTS

John and William Bartram, Botanists at the time of our Nation's Birth. ARTHUR T. GUARD, Purdue University, West Lafayette, Indiana 47907.—The area of the thirteen colonies and later the first states of our nation was a veritable Garden of Eden for botanists. However, most early settlers were too busy with other pressing problems to take advantage of this plethora of plant life. The Bartrams' botanical studies have been left to us through their accounts of their travels and especially William's book, "The Travels of William Bartram", 1791.

A Backward Look at Academy Presidential Addresses. RAYMOND E. GIRTON, Department of Soils and Plant Nutrition, University of California, Berkeley, California 94704.—In retrospect the fifty-year period (1973-23) included 20 presidential addresses in the area of biology, 14 dealing with educational subjects, four classified as ecology, three each in chemistry, geology, and pharmacy, two in physics, and one in mathematics.

Ten-year-period trends show a decline in biology addresses from five to two, whereas those classed as education began with two and remained constant at three addresses each over the last four decades. Ecology addresses were given in three of the five decades: two in the 1963-54 decade and one each in the second (1943-34) and in the last decade (1973-64). Two chemistry addresses were read in the 1973-64 decade and one in the 1953-44 decade, whereas one pharmacy address was given in each decade of the 1973-44 period. Three addresses relating to geology were presented in alternate decades beginning with the first. The two physics addresses were both given in the earliest period whereas the one in mathematics was presented in the middle period.

As to the 17 institutions represented, Purdue with 10 and Indiana with 9 addresses headed the list. DePauw and Notre Dame each were represented by five addresses, Eli Lilly & Co. by four, and Indiana State by three. Ten other institutions contributed one or two addresses each.

The remainder of this paper is devoted to sketching individually the more recent addresses—those of the 1973-48 period. These include the subjects of biology (8 addresses), education (7), ecology and pharmacy (3 each), chemistry (2), and geology and mathematics (1 each).

Describers of the Indiana Fauna—A Bicentennial Study (Progress Report) B. ELWOOD MONTGOMERY, 906 North Chauncey Ave., West Laf-

ayette, Indiana 47906.—In 1973 a study was presented to this section on the Linnean “elements” in the Indiana Fauna and Flora (7), in which the number of taxa in selected groups of the Indiana Biota named by Linnaeus were presented. During the bicentennial years this study is being extended to determine other authors of genera and species of animals known to occur in Indiana and to tabulate the dates at which the taxa were described. These data are being compiled from available state lists and catalogues; those used thus far include: Ensifera-McCaffert & Stein (4), Odonata-Williamson’s and Montgomery’s published records, as cited in the 1971 paper (6), Pisces-Gerking (2), Amphibia and Reptilia-Minton (5), Aves-Mumford (8) and Mammalia-Lyon (3). None of these furnish all the information on authors and dates desired, but this has been obtained from other sources, especially Neave’s Nomenclator (9) and the A.O.U. list (1). However, complete information of the dates of descriptions of the species of several groups has not been secured yet.

It should be noted that few of the authors were ever in Indiana and that most of the species were originally described from other areas, some far removed from the state. Of the authors who did work, or visit, Indiana, all worked on material from wide areas and their “Indiana” species are likely to have been described from other regions.

The political history of the country may have had little direct effect upon the activity of taxonomists, but it may be interesting to compare such activity as measured by the number of taxa described with certain periods of national and state development:

- 1758 Beginning of our system of zoological nomenclature
- 1759-1774 The colonial period
- 1775-1783 The Revolutionary period
- 1784-1815 (Indiana) territorial period
- 1816-1825 Early statehood period
- 1826-1834 The New Harmony period

The beginning of our system of nomenclature came during the colonial period, and there had been considerable biological exploration in this country before that time, but none in or near Indiana. Of course, the colonial period began much earlier but the biological activity cannot be reflected by the date of establishment of taxa before the beginning of the accepted system of names. Some biologists, as Audubon and Rafinesque, even Say on the way to his western and north-western explorations, visited Indiana during the early statehood period. There appears to be no reflection of such visits in the published descriptions by these authors, however.

Listing of the Indiana taxa by authors is in progress but will require much more work for completion as some of this information is not readily available and the identification of the authors even when their names are known has not been possible yet.

TABLE 1. *Tabulation of the dates of description of genera and species of selected groups of animals listed as known from Indiana*

Periods	Ensifera	Odonata	Pisces	Amphibia	Reptilia	Aves			
						"Water" birds	Passi- formes	all birds	Mammalia
1758	-----22- 1	1- 2	5-1	1-1	2-1	5-35	9-38	27-127	13-10
1759-1774	-----0- 6	0- 6	2-	3-	1-	4- 9	3-26	21-58	1-2
1775-1783	-----0- 2	1- 1	1-	0-	0-	0- 4	0-12	0-12	4- 9
1784-1815	-----1- 0	5- 6	7-	0-	5-	4-10	13-50	31-85	11-16
1816-1825	-----1- 1	0- 0	28-	4-	3-	11- 2	12-13	26-27	7-13
1826-1834	-----1- 1	1- 0	4-	0-	5-	8- 2	16-12	40-21	8- 7
1835-1865	-----8-20	23-90	30-	7-	13-	11- 7	28-14	55-25	13-20
1866-1899	-----5-28	13-23	15-	0-	2-	0- 0	0- 0	0- 0	6-14
1900-date	-----8-21	8-17	3-	0-	0-	0- 2	0- 0	0- 2	2- 7
Totals	-----26-80	52-145	93-182	15-42	34-63	45-70	45-70	221-358	66-99

¹The state lists which were used to compile the data for these groups did not cite year of description; dates of establishment of the genera have been obtained from Neave, 1939 (9), but those for the species have not been obtained.

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**"A Social Lamarckism Crisis in American
Reform Thought: Lester Frank Ward"**

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The late nineteenth-century announcement of August Weismann's findings in regard to the impossibility of inheriting acquired characteristics created a crisis of confidence among a school of American social reformers who prided themselves on the scientific basis of their evolutionary reform thought and who had consistently sought to appropriate the aura of scientific reliability to validate their reform programs. Most striking of these reformers who believed in an immediate, monistic application of natural scientific ideas to human society was Lester Frank Ward. Ward, a paleobotanist with the United States Geological Survey and a founder of sociology in this country, led an attack on Weismann's conclusions in fear that they would undermine Ward's program of melioristic and nationalistic reforms generally centered on educational programs.

Lester Ward, along with nearly all American biologists and social philosophers of the generation following the Civil War, accepted the idea of biological transmission to their descendants of certain characteristics acquired by organisms during their lifetime. The concept itself was quite old, an established element in the folk-beliefs of Western culture, but early in the nineteenth century it received a scientific formulation and the name of its formulator, Chevalier de Lamarck, a French naturalist. Lamarck held that the habitual exercise of an organ by any creature increased the capacity of the organ and that any structural modifications were preserved thereafter through biological inheritance. Charles Darwin, as well as most early Darwinians, accepted Lamarckism as one source of the variation in species which provided the occasion for the operation of natural selection. The young Ward, like other early supporters of evolutionary theory, was happy to accept theoretical support wherever it might be found, and given the very real inadequacies in Darwinian theory to explain the origin of variations, he too brought Lamarck into service. In Ward's case, the acceptance of Lamarck by Auguste Comte and Herbert Spencer, his key intellectual mentors, served to confirm his acceptance of the idea.

Just as important to Ward as the biological necessity of Lamarckism to help explain the origin of variability, was its sociological utility. American reformers, because of the very history of their society and its ethos, were drawn to environmental and institutional programs of reform as those most consistent with American values and aspirations; Ward was an embodiment of such a position. For such people, Lamarckism provided a source of legitimacy in validating the efficacy of social reform; the improvements of one generation, like their sins, could be passed on to subsequent generations. From this foundation it was

possible to affirm a belief in unilinear progress for American society and to create the public opinion necessary for providing the financial and political support needed by most reform movements (2).

Lamarckism, like other early scientific concepts based on shrewd guesses and philosophical conclusions, was shy of empirical proofs and experimental confirmations. In fact, it was particularly vulnerable to association with crude tales of the inheritance of mutilations and marks on the offspring of women traumatized during pregnancy. In the late 1880's, evolutionary scientists and social reformers who rested their premises on biological evolution were forced to reconsider their Lamarckian assumptions because of the experimental evidence offered by a German embryologist at the University of Freiburg, August Weismann.

In studies conducted during the 1880's, and first published in English in 1889, Weismann sought to demonstrate that because of the nature of cellular action at the heart of the reproduction process, only germ—or sex—cells were involved; there was no way for the more ordinary body—or somatic—cells to influence the hereditarian transmission carried by the germ-plasm. Acquired characteristics gained through exercise or from the effect of environment could not be passed on to progeny; an organism could inherit only those traits provided in the make-up of the germ-cells of its parents. Natural selection alone, concluded Weismann, operating on the variations created by the complex union of ancestral germ-plasms from dual parents and by less-well-explained genetic "sports," or mutations, explained the processes of biological evolution. Darwin, now dead, was out-Darwined by the exclusive prominence given to natural selection by the adherents to Weismann's conclusions; and the Neo-Darwinians, as they were soon called, moved to strike Lamarckian conceptions from evolutionary theory and to minimize the evolutionary role of sexual selection and mutations.

Lester Ward, confronted with Weismann's challenge to his understanding of biological evolution and evolutionary social reform, as well as being faced with the necessity of preparing a presidential address for the Biological Society of Washington, spent the summer of 1890 bouncing in a buckboard over the Triassic terrain of Maryland and Virginia while engaged in Geological Survey work, reading Weismann and drafting his response. In his address, as later, Ward's critique was based on criticisms of Weismann's logic and support for Ward's own ideological needs, since his personal work in paleobotany and sociology left little time or inclination for work in experimental embryology. When his address on "Neo-Darwinism and Neo-Lamarckism" finally emerged, it took the form of a vigorous criticism of Weismann's "hypotheses" and a reaffirmation of the "laws" of Neo-Lamarckism (4).

The warmth of Ward's reply suggests that in the absence of a concept of culture severed from all biological connections, to abandon Lamarck while accepting Weismann was viewed by him as an abandonment of the social sciences to unrestrained biological determinism (2). The difficulty for Ward in parting company with Lamarck was the absence of an alternative theory of culture with scientific authority that could legitimize the efficacy of social reform activity. Before

Weismann it had been possible in Lamarckism to emphasize the cultural aspect of a mixed socio-biological process, but now at first flush it seemed necessary to Ward to choose between race and culture. The nature of cultural change had not yet been severed from the biological processes that found shelter in the muddled biocultural terminology of Lamarckism.

Ward's lecture to the Washington area biologists in early 1891 initiated a spirited campaign of several years by him to maintain room for Lamarckism in evolutionary theory. During the campaign, however, Ward conceded increasing territory to the Neo-Darwinians. The contest continued into the early 1900's for Ward, as it did for many other American social scientists, although the evidence in his work of that decade suggests that he reluctantly gave up Lamarck as the weight of contrary evidence accumulated and as he recognized more hostile deterministic forces in the eugenics movement. Yet the importance of Lamarck to his social thought makes "social Lamarckism" as accurate a description of Ward's thought as does the more commonly ascribed designation of "social Darwinism (1)."

Ward based his defense of Lamarckism on two main grounds: the failure of Weismann to provide a satisfactory explanation of the appearance of variations and the very limited knowledge yet confirmed about the very minute and largely unknown processes of inheritance. The verdict was not yet in, Ward contended, and until it was, Lamarck's reliability should be presumed given the assistance his ideas had provided Darwin and the pragmatic value they retained for influencing public support of social action. Ward did not spare Lamarck in his critique, however. The French naturalist, according to Ward, had not recognized the operation of natural selection, and Ward never doubted that that process was much more instrumental in the course of evolution than Lamarck's "law of exercise." Many of the examples of variation credited to acquired characteristics, he admitted, were no doubt less clearly understood actions of natural selection. And the tendency of Lamarck and later proponents to believe that accidental mutilations could be transmitted to offspring was disavowed by Ward, although he accused the Neo-Darwinians of continuing their fire on such strawmen.

In Weismann's work, Ward was particularly critical of how the embryologist could explain hereditary variation if environment could not cause specific changes and if the substance of germ-plasm could only be explained by referring it back further to more ancestral germ-plasm. From whence, Ward questioned, could the ancestral variations have appeared? Both Weismann and Ward at this time minimized mutations, although Ward was able later to accept mutations as a substantial replacement for acquired characteristics since his ego found consolation in his own earlier "fortuitous variation" theory of heredity that came close to the concept of mutations (3).

On the issue of acquired characteristics, Ward's paleontological orientation using fossil evidence was a handicap. Not coincidentally, many of the strongest critics of Weismann in America were paleontologists, including men like Edward D. Code, Henry Fairfield Osborn, Alpheus Spring Packard, and John A. Ryder. The nature of their evi-

dence differed dramatically from that of the experimental embryologists since the evolutionary series they were able to reconstruct were biased toward evolutionary successes which demonstrated functional variations and since the distance in time from the variations studied led them to credit changes to the influence of the powerful climatic and environmental forces that their work also uncovered.

In his critique of Weismann, Ward professed to be unable to comprehend how his adversary could argue that climate, temperature, and nutrition were able to create variation in the germ-plasm, but still reject the idea of acquired characteristics. Weismann had been forced to concede that environmental agents might have some random genetic effects, but he insisted quite rightly that this was not the same as saying that an organism could transmit functional modification to its offspring through its own efforts. Apparently the overlapping arguments of environmental influences and the much more narrow and teleological idea of the inheritance of structural modifications through exercise and exertion confused the issues. Ward's argument was further weakened, given his minimization of fortuitous variation in 1891, by his apparent assumption that most variations were functional as a result of the Lamarckian phenomenon despite the fact that numerically most variation was clearly nonadvantageous and often disadvantageous.

The transmission of heredity, Ward conceded, was a subtle process not yet fully understood. He was unable to supply evidence to support his modified Lamarckian beliefs, but, he insisted, neither was Weismann able to demonstrate empirically the source of variation. "The truth is," Ward suggested at one point, "that the real phenomena of heredity are too recondite for direct observation (4)." Nevertheless, he argued defensively, the burden of proof rested on the embryologists and until that was supplied the idea of the inheritance of acquired characteristics should be accepted because of its pragmatic utility.

By utility, Ward, of course, referred to the effect that scientific ideas might have on human behavior. The importance of Ward's automatic intellectual reflex to draw the social implications from a debate in the nature of biological evolution became clear in the concluding remarks of his Washington address and in his later amplification of those ideas in an article for laymen (5). Unfortunately, the urge to judge his scientific ideas by a test of their pragmatic value to society locked Ward in to his Lamarckian position. What most exasperated him about Weismann, he admitted, was the contention that environment could affect germ-plasm in only an irrational, haphazard fashion, while application, effort, and the habits of the organism were of no account. "If nothing that the individual gains by the most heroic or the most assiduous effort can by any possibility be handed onto posterity," he wrote, "the incentive to effort is in great part removed. If all the labor bestowed upon the youth of the race to secure a perfect physical and intellectual development dies with the individual to whom it is imparted, why this labor (4)?" In short, Weismannism was a socially immoral and un-American ethic.

What Ward feared was that Weismann's conclusions would bolster the proponents of *laissez-faire* and of social determinism. If effort and

social reform could not change man, then it was absurd to try. The public's tenuous financial support to education was particularly in jeopardy, he believed, by this new refinement in "nature-worship." Consequently, it was to the effects on education of the debate between the Neo-Lamarckians and the Neo-Darwinians that he devoted his popular writing on heredity. While most mental traits were non-advantageous in the struggle for survival, Ward contended, those of cunning, money-getting, and political intrigue had held survival value as had the competitive traits in lower animals. But the higher intellectual and ethical faculties, he maintained, had not been advantageous in a competitive jungle and could only have survived through other than natural selection processes. The growth of capacity, which he assumed in those traits, could only have been created by the incremental increases of each generation that exercised their brain cells and transmitted the structural increase to their progeny.

The Neo-Lamarckians, he stressed, had never believed that knowledge or culture were transmitted directly to descendants through inheritance. Only the *capacity* for acquiring knowledge was hereditary. Each generation had to acquire anew the knowledge that humanity had accumulated—a sufficiently discouraging circumstance in itself. Yet the social need was imperative; each generation had to replenish and exercise the store of knowledge or else both the social inheritance of the knowledge content and the biological inheritance of cellular capacity would diminish. The struggle had always been uphill, he suggested, so the "comforting popular belief" in the transmission of acquired characteristics had emerged to bolster the morale of those in that struggle. While this pragmatic explanation for the origin of the idea suggests that Ward was less than sure of the scientific accuracy of Lamarckism itself, he feared any immediate acceptance of Weismann would dangerously weaken the public's resolve to support education and the social ethic of work on which he believed civilization depended. So, he concluded, "until the doctors of science shall cease to differ on this point and shall reduce the laws of heredity to a degree of exactness which shall amount to something more like a demonstration than the current speculations, it may perhaps be as well to continue for a time to hug the delusion (5)."

Ward continued the Neo-Lamarckian debate up to the mid-1890's, but in substance he conceded territory to Weismann at the same time that he proclaimed Weismann's concessions (6, 7, 8). Once Weismann was willing to accept the genetic influence of climate and nutrition on the germ-plasm, however, Ward was apparently satisfied that environment as an important biological and social force was preserved as a weapon against the naturalistic determinists, and he edged out of the debate. Lamarckism had become the symbol for environmentalism, but once the broader environmental principle had been accepted in however muted a fashion, Ward was willing—though reluctantly—to abandon his overt espousal of the inheritance of acquired characteristics.

In *Pure Sociology*, written in 1902, Ward still championed Lamarckism as it applied to the mind, or brain, but, paradoxically, he now accepted Weismann as the authoritative spokesman for an explanation

of the inheritance process (9). The acquisition of knowledge, "the social germ-plasm," he acknowledged, followed social processes unlike those in biology. "Organic and social heredity are not the same and cannot be interchanged," he wrote, as he prepared his retreat from Lamarck. "We may be spared," he concluded, "from entering into the endless and hopeless discussion of the transmission of acquired characters."

By the time Ward's *Applied Sociology* was published in 1906, he no longer mentioned the inheritance of acquired characters, credited himself with supplying new information to Weismann, and in his brief discussion of genetic inheritance placed himself in full accord with the matured Neo-Darwinian position (10). "This view," he now found, despite a lingering trace of Lamarck, "has its hopeful or optimistic side, for, as we have seen, nothing is ever wholly lost, and the accumulations of unnumbered generations continue to exist, . . . ultimately to come forth and exert their due influence upon the world." The Weismannism that had once seemed to threaten activist reform efforts finally had been domesticated by Ward to serve as a supporting rationale for reform replacing the now-discredited Lamarckism.

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MICROBIOLOGY AND MOLECULAR BIOLOGY

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was elected Chairman for 1976

ABSTRACTS

Callus and Cell Suspension Cultures of Maize. T. H. OSWALD and R. L. NICHOLSON, Department of Botany and Plant Pathology, Purdue University, West Lafayette, Indiana 47907.—(Presented at 1974 meeting, erroneously omitted from *Proceedings* of 1974). A modified Linsmaier and Skoog medium was used for induction of callus on mesocotyls and roots of maize seedlings. Amendments with vitamins and an increased concentration of chelated iron accelerated callus induction 3 fold, compared with the rate of callus induction on the medium lacking these modifications. Continued growth of excised callus, through repeated subcultures, was possible by lowering the concentration of sugar and adjusting the balance of mineral nutrients, in addition to maintaining the increased concentration of chelated iron and providing the vitamin supplements. Cell suspension cultures were established from callus placed in liquid medium in which the chelating agent was omitted. This liquid preparation contained non-chelated iron, acetate and the aforementioned modifications.

Comparison of Growth Rate and Mycelial Density of *Rhizoctonia Solani* on an Ammoniacal and Nitrate Source of Inorganic Nitrogen. CYNTHIA M. KUIVENHOVEN, D. M. HUBER, and H. L. WARREN, Department of Botany and Plant Pathology, and ARS-USDA, Purdue University, West Lafayette, Indiana 47907.—(Presented at 1974 meeting, erroneously omitted from *Proceedings* of 1974.) The form of nitrogen fertilizer used greatly influences the severity of plant diseases caused by *R. solani*. Nitrate nitrogen ($\text{NO}_3\text{-N}$) reduces stem canker of potato and other *Rhizoctonia* diseases, while Ammonical nitrogen ($\text{NH}_4\text{-N}$) may increase severity. To determine if the form of nitrogen exerted a direct effect on growth of the pathogen, various isolates of *R. solani* from several hosts were grown on cellophane membranes overlying a modified Czapek-Dox agar medium containing either $\text{NO}_3\text{-N}$ or $\text{NH}_4\text{-N}$ as the nitrogen source. Although differences in lineal growth were observed between isolates, there were no differences in growth rate attributable to nitrogen source. Mycelial density was also similar for the two forms of nitrogen when the medium was strongly buffered to prevent a low pH with $\text{NH}_4\text{-N}$. Pectolytic and cellulolytic enzymes were produced with $\text{NH}_4\text{-N}$ but not with $\text{NO}_3\text{-N}$. This data suggests the form of nitrogen influences *Rhizoctonia* diseases by affecting pathogenicity rather than growth of the pathogen.

NMR Characterization of ADP-ATP Translocase. WILLIAM S. KAIN, Indiana State University, and WALTER X. BALCAVAGE, Center for Medical Education, Indiana University School of Medicine, at Indiana State University.—(Presented at 1974 meeting, erroneously omitted from *Proceedings* of 1974.) The NMR spectra of ADP-nucleotide translocase complexes show enhanced spin relaxation of H_8 on the purine ring in the presence of mitochondrial ghosts. This effect is atractyloside sensitive. Atractyloside added to the complex induced further H_8 peak broadening at half maximal concentration of $4 \mu\text{M}$ with 20 mg/ml membrane protein. Atractyloside added before ADP eliminates the specific H_8 peak broadening. No spin relaxation effects are seen at the H_2 proton. Assuming a binding site concentration of 600 p moles per mg protein, the lifetime of the ADP-translocase complex can be calculated to be approximately 20μ sec. Similar calculations show the lifetime of the ADP-Translocase complex in the presence of atractyloside to be about 46μ sec. EDTA competes with ADP for binding to the translocase, reversing the NMR peak broadening and EDTA inhibits state 4 to state 3 respiratory transitions. A lipid free aqueous suspension of mitochondrial membrane proteins causes effects on the NMR spectrum of ADP identical to those described above. The spin relaxation phenomena shown here are consistent with a model of the translocase containing a paramagnetic metal, at or near the active site.

Induction of Resistance in Cucumbers and Recognition of the Presence of a Compound Fungitoxic to *Cladosporium Cucumerinum*. G. S. ACRES, R. E. HAMMERSCHMIDT, and J. KUC, Department of Biochemistry, Purdue University, West Lafayette, Indiana 47907.—(Presented at 1974 meeting, erroneously omitted from *Proceedings* of 1974.) Eight-day-old cucumber (*Cucumis sativus* L.) seedlings, resistant or susceptible to scab and all susceptible to anthracnose, were inoculated with *Colletotrichum lindemuthianum* (Sacc. and Magn.) Schribner beta race, bean anthracnose causal agent, *Colletotrichum lagenerium* (Pass.) Ell. and Halst. race 1, causal agent of cucurbit anthracnose, or *Cladosporium cucumerinum* Ell. and Arth., cucumber scab causal agent. Scab susceptible plants were found to have resistance to scab induced when treated with *C. lindemuthianum* 24 hours prior to a challenge with *C. cucumerinum*. Plants susceptible to anthracnose, but resistant to scab, had resistance to anthracnose induced by treatment with *C. cucumerinum* 24 hours prior to a challenge with *C. cucumerinum*. Plants susceptible to anthracnose, but resistant to scab, had resistance to anthracnose induced by treatment with *C. cucumerinum* 24 hours prior to a challenge with *C. lagenerium*. Water extracts of etiolated seedlings of two genetically similar varieties, except with respect to scab resistance, were dialyzed against water, and the membrane permeable fraction saved. Two compounds were found by paper chromatography that fluoresced under UV light and reacted with diazotized sulfonilic acid. UV quantitation showed the same high level of the compounds in scab infected and healthy resistant tissue. Less was found in healthy susceptible tissue and the least in infected susceptible tissue. An on chromatogram inhibition assay, OCIA, showed that one of the spots inhibited the growth and germination of *C. cucumerinum*.

Preferential Assignment of Allotype al Globulin for Production of Early IgM anti-p-azophenylarsonate Antibody in al, a3 Heterozygous Rabbits. C. C. CHIEN and J. S. INGRAHAM, Department of Microbiology, Indiana University School of Medicine, Indianapolis, Indiana 46202.—(Presented at 1974 meeting, erroneously omitted from *Proceedings* of 1974.) It has been observed that in some rabbits with immunoglobulin of allotype al, a3 the IgG anti-arsanilazo antibody is chiefly or perhaps exclusively of allotype al. (Zimmerman et al., *Fed. Proc.* 32, 1014 (1973). For the present study, a group of seven rabbits with immunoglobulin of allotype al, a3 was immunized with a mixture of p-azophenylarsonate (AA) pigeon red cell stromata and p-azophenyl-N-trimethylammonium (TMA) pigeon red cell stromata intravenously on days 0, 2, and 4, and blood lymphocytes were isolated by the Ficoll-Hypaque technique on day 6. Two of the animals were autopsied on day 6 and spleen cells were also examined. The proportion of the antibody-forming cells in these lymphocytes which were making IgM anti-AA antibody of allotype al or a3 was estimated by inhibition of hemolytic plaque formation on AA-sheep RBC by means of anti-allotype antisera. In seven animals of allotype al, a3 the number of anti-AA plaque-forming cells (PFC) was inhibited 71% (45-99%) by an anti-al antiserum and only 13% (1-30%) by an anti-a3 antiserum. In the same animals, the number of anti-TMA PFC was not inhibited by the same anti-al antiserum, except for spleen cells from one animal which were inhibited by 30%. However, inhibition of the TMA PFC by the anti-a3 antiserum was 34% (1-69%). Thus, it appears that the great majority of the anti-AA PFC were making antibody of allotype al. Subsequent study of specific inhibition of the anti-AA hemolytic activity in the sera of some of these animals also showed the activity to be carried chiefly by molecules of allotype al. On the contrary, by the same criteria, the activity of anti-TMA appears to be higher in the a3 than in the al. It seems of interest to inquire whether this preferential selection of one allotype of globulin over the other in anti-AA immune response is simply a fortuitous aspect of the genetics of these animals or if it reflects a significant aspect of the structural properties of the allotypic globulins in relationship to certain antigens.

Factors Affecting Bacterial and Fungal Growth in Total Parenteral Nutrition Solutions. M. L. FAILLA, D. D. BENEDICT,* and E. D. WEINBERG, Department of Microbiology, Indiana University, Bloomington, Indiana 47401.—(Presented at 1974 meeting, erroneously omitted from *Proceedings* of 1974.) Growth of starved bacteria and yeasts in the components of and in complete parenteral nutrition solutions (TPN) prepared with 8.5% Freamine, 5% Aminosol, or 10% vitamin-free Casamino acids was examined. Yeasts grew well in all TPN solutions employed, whereas bactericidal effect observed in TPN-Aminosol was overcome by raising its pH of 5.1 to 6.1 (the natural pH TPN-Freamine). The bactericidal nature of TPN-Freamine was altered neither by increasing the pH to neutrality nor by decreasing its osmolality. However, when Freamine was diluted threefold or greater prior to its incorporation in the TPN solution, bacteria were able to grow rapidly; this suggests

*Represents author presenting paper.

that the bactericidal activity may result from the concentration of certain amino acids or other factors inherent in the Freamine solution. The effects on growth of supplementation of TPN solutions with metals, vitamins and inorganic phosphate (Pi) were also observed. In diluted TPN solutions, exogenous Pi greatly enhanced bacterial growth. Results of this study may provide useful information concerning the high incidence of secondary bacterial and yeast infections associated with TPN therapy.

The Growth and Decomposition of *Chloroflexus-Synechococcus* Microbial Mats in Alkaline Thermal Springs. T. PARKIN, J. C. COOK, and W. N. DOEMEL, Wabash College, Crawfordsville, Indiana 47933.—The growth and decomposition of a *Chloroflexus-Synechococcus* microbial mat in a thermal spring located in the Lower Geyser Basin, Yellowstone National Park, Wyoming, was studied with silicon carbide (carborundum) as a neutral substratum. Silicon carbide was placed onto the microbial mat with a template. The increase of mat thickness and Lowry protein above the silicon carbide (growth) was monitored regularly by collecting a coring of the mat over the silicon carbide with a standard cork borer. A second layer of silicon carbide was placed over this new mat when about 2 mm had accumulated. The decrease of mat thickness and Lowry protein (decomposition) between these two layers was then monitored in the same way. From these data, rates of growth and decomposition were determined. In this microbial mat and in other mats in similar pools, the rate of decomposition approximated growth rate so that there was little net accumulation of mat above a "foundation level." At these temperatures, eukaryotes are absent so that prokaryotic microorganisms are responsible for all of the decomposition. This is contrary to a general opinion that eukaryotes, particularly insects, are necessary for decomposition to be significant.

The Structure of *Chloroflexus-Synechococcus* Microbial Mats in Alkaline Thermal Springs. WILLIAM N. DOEMEL, Wabash College, Crawfordsville, Indiana 47933.—The filamentous photosynthetic bacterium *Chloroflexus* (bacteriochlorophylls a and c) independently and in association with the blue-green alga (Cyanobacterium) *Synechococcus* (phycocyanin and chlorophyll a) forms laminated mats in alkaline thermal pools between 55 and 65 C. At night or in the absence of algal photosynthesis, *Chloroflexus* migrates upwards covering the mat with a thin orange-pink layer. *Chloroflexus* also forms a number of differentiated structures on the mat—"nodes," 0.5-1.0 mm conical projections; colonies—circular, flat orange growths with green centers; and streamers. Ultra-thin sections of microbial mat show vertical, horizontal, and alternating vertical and horizontal arrays of *Chloroflexus*. The laminated structure of the mat is similar to fossil stromatolites and suggests that photosynthetic bacteria, like *Chloroflexus*, may have formed some of these structures rather than filamentous blue-green algae.

Fluorescent Whitening Agents: Effects on Selected Algae. A. BROOKS and W. DOEMEL, Wabash College, Crawfordsville, Indiana 47933.—The impact of fluorescent whitening agents (optical brighteners) on the growth and photosynthesis of *Chlorella* and *Microcystis* was investigated.

Polar optical brighteners bound strongly to cellulose and to algae with cellulose walls while semi-polar and non-polar optical brighteners did not bind to most algae. Since most optical brighteners absorb in the ultra-violet and fluoresce between 400-5—nm, algal photosynthesis could be enhanced; however the uptake of ^{14}C -bicarbonate by *Chlorella*, *Microcystis*, and natural populations of algae was unaffected by either polar or non-polar optical brighteners. Since optical brighteners bind to the wall of *Chlorella*, growth might be inhibited by disruption of transport mechanisms; however, the growth of *Chlorella* was not inhibited by polar optical brighteners at 2.5 ppm. Since natural concentrations of optical brightener range between 0.0015 and 0.015 ppm, these observations suggest that natural concentrations of optical brighteners would have no effect upon natural algal populations.

Effects of Defined Microflora on Bile Acids of Gnotobiotic Rats. D. MADSEN, M. WAGNER, and B. WOSTMANN, Department of Microbiology, University of Notre Dame, Notre Dame, Indiana 46556.—The bile acids (BAs) hyodeoxycholate (HDC) and ω -muricholate (ω -MC) are both absent from germ-free (GF) Lobund/Wistar rats, but in the conventional animal they comprise about 50% total excreted (fecal) BAs. Body pools of both neutral and acid sterols are larger in GF than in CV rats. Since BA excretion is the major pathway for removal of body cholesterol, and because HDC and ω -MC appear *not* to be greatly reabsorbed during passage through the gut, we have postulated that in the CV rat the potential to form these two BAs serves to control body cholesterol pools.

We have become interested in identifying the bacterial species responsible for initiating production of HDC and ω -MC, presumably from the primary BA, β -MC. More specifically, we wanted to know if initiation of this pathway is a property of many or of only a selected few of the bacterial species in the rat gut.

One experiment involved GF rats which were accidentally contaminated with a single species of a diphtheroid. This organism partially deconjugated all BAs present, and formed keto BAs. However, neither HDC, ω -MC, or deoxycholate were found in feces.

Another experiment made use of rats associated with a defined hexaflora developed at the Lobund Laboratory. The hexaflora contained: *Lactobacillus brevis*, *Streptococcus faecalis*, *Staphylococcus epidermidis*, *Enterobacter aerogenes*, *Bacteriodes fragilis* var. *vulgatus*, and *Torulopsis* sp. Although fecal BAs were partially deconjugated, again no deoxycholate, HDC, or ω -MC were found, nor were derivatives of cholesterol; keto-acids in feces were within the range found in CV rats.

These results indicate that the capacity to produce the secondary BAs mentioned above is found in relatively few bacterial species of the rat gut, especially when compared to the capacity to deconjugate and to form keto BAs. (Supported by the National Institutes of Health and the Fannie E. Rippel Foundation.)

Inactivation of Microorganisms by Simultaneous Treatment with Ozone and Ultrasonics. GARY BURLESON and MORRIS POLLARD, Lobund Laboratory, University of Notre Dame, Notre Dame, Indiana 46556.—The

effects of ozone, ozone and sonication, or sonication on microorganisms with public health significance were investigated. Microorganisms suspended in phosphate-buffered saline were rapidly inactivated by treatment with ozone. Microorganisms suspended in secondary effluent from a wastewater treatment plant required longer contact times with ozone for complete inactivation. Simultaneous treatment by ozonation and sonication reduced the contact time for complete inactivation of microorganisms in secondary effluent. Since sonication alone or sonication with oxygenation did not inactivate test bacteria, the enhanced inactivation by simultaneous treatment with ozone and ultrasonics is interpreted as a synergistic effect.

Decontamination of Gnotobiotic Mice Monoassociated with *Candida albicans*. MORRIS WAGNER and KUNWAR K. SRIVASTAVA, Lobund Laboratory, Department of Microbiology, University of Notre Dame, Notre Dame, Indiana 46556.—Candidiasis is a common health hazard in patients undergoing physical and/or drug treatment associated with organ transplantation and neoplastic diseases. It is also a problem in infectious disease patients receiving broad spectrum antibacterial antibiotics that alter the normal intestinal flora. In the present investigation, germfree AKR mice were monoassociated with *Candida albicans* and used as a model to determine whether such mice could be decontaminated successfully and returned to their earlier germfree state by oral treatment with amphotericin B. This model could provide useful information for the control of candidiasis in patients.

C. albicans became well established in gnotobiotic mice ($\log_{10}$ of number per gram of organ plus contents averaged 7.9 and 7.7 in stomach and cecum respectively). Direct fecal smears as well as impression smears of the stomach and cecal mucosal surfaces revealed yeast-phase cells, many with germ tubes, but no mycelium. No illness or mortality was observed over a four-week acclimatization period. The mice were then given *ad libitum* amphotericin B dissolved in the drinking water. At levels of 0.1 and 0.2 mg/ml, the number of *C. albicans* decreased but the organism was not eliminated completely. However, 0.3 mg/ml was sufficient to decontaminate the mice completely and return them to the germfree state. Residual amphotericin B was detected in the feces of mice receiving the high 0.3 mg/ml level only. These mice tested germ-free after 4 weeks of treatment at this level and continued to test germ-free until the termination of the experiment ten weeks after the antibiotic had been discontinued and replaced by plain drinking water.

The Use of Liposomes to Enhance the Antiviral Activity of Polyuridylic Acid. THOMAS J. TINGHITELLA and CHARLES F. KULPA, Department of Microbiology, University of Notre Dame, Notre Dame, Indiana 46556.—Recent studies with artificial multilamellar phospholipid vesicles (liposomes) which are similar to natural membranes have shown their potential as general carriers of therapeutic agents. The properties of liposomes may in effect enhance the activity of the enclosed chemotherapeutic agent.

Liposomes themselves are easily prepared. Phospholipids are dried in a round-bottom flask using a rotary evaporator; the material to be

enclosed is dissolved in water, then added to the dried lipids. Vigorous agitation results in the spontaneous formation of these lipid vesicles. Cholesterol may be added to the phospholipids to increase the stability of the structures produced. The presence of long chain cations or anions increases the spacing between vesicle bilayers and adds a net negative or positive charge.

Using either neutral or charged liposomes we attempted to enhance the inhibitory activity of the synthetic RNA polymer, polyuridylylate against vesicular stomatitis virus. *In vitro* poly U is an effective inhibitor of the polymerases needed for replication of RNA viruses. However, little or no activity of free poly U is demonstrable against the replication of vesicular stomatitis and other RNA viruses in cell culture. This may be due to rapid extracellular degradation or the inability of the cell to take up the polymer.

Our studies have shown that poly U can be protected from degradation when it is enclosed in liposomes. Negatively charged liposomes enclosing poly U were found to be ineffective against VSV replication while liposomes with a net positive charge and containing poly U had an inhibitory effect on VSV replication.

Functional Bile Acid Patterns in Gnotobiotic Mammals. BERNARD S. WOSTMANN and MARGARET H. BEAVER, University of Notre Dame, Lobund Laboratory, Notre Dame, Indiana 46556.—Many gastro-intestinal studies would benefit if the experimental model included the possibility of control and definition of the microbial variable. These include studies on digestion and absorption, on intestinal motility and excretion, and aspects of experimental surgery.

Many functional aspects of the gut may be affected by the qualitative and quantitative composition of intestinal bile acids (BA). These include solubilization of lipids, lipase action, energy dependent transport, renewal rate of the intestinal mucosa and its cell age-dependent enzyme systems, etc. We have compared germfree (GF) versus conventional (CV) states of mammals (rat, mouse, gerbil, pig, dog, rabbit, and human) to determine the effect of microflora on BAs.

BA patterns of CV rats and mice differ greatly from GF, due to the production of the primary BAs cholic and β -muricholic acids, and to the presence of the large rodent cecum. The gerbil and rabbit produce only chenodeoxycholic and cholic acids, but possess sizeable ceca, and show major differences in GF and CV functional BA patterns. This is also true of the pig which produces cholic and hyocholic acids, although the microbial reservoir (cecum) is virtually absent. The dog, with cholic acid as the major primary product, shows the smallest qualitative and quantitative difference in functional BA patterns between the GF and CV states.

These observations suggest the gnotobiotic dog as a model of choice for studies of gastro-intestinal function which require control of the intestinal microflora. While a quantitative resemblance exists between BAs of dog and human, the qualitative human BA pattern resembles that of the gerbil more than of the dog. (NIH and Fannie E. Rippel Foundation.)

Characterization of Three Species of the Genus *Colletotrichum* with Aminopeptidase Profiles¹

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Abstract

Aminopeptidase activity of *Colletotrichum coccodes* isolated from potato stems, tomato roots, and tomato fruits, *C. graminicola* isolated from sweet and dent corn, and *C. gloeosporioides* isolated from tomato fruit, was determined with a fluorometric aminopeptidase assay. Tubes containing 1.9 ml of each of 22 amino B-naphthylamide substrates ($2.5 \times 10^{-5}M$ in 0.05M Tris buffer pH 8.0) were inoculated with 0.1 ml inoculum. Inoculum was prepared by homogenizing fungal tissue harvested from 7 day PDA plate cultures in 0.05M Tris buffer pH 8.0 with a final concentration of 0.1 g fungal tissue per 10 ml buffer. Enzymatic activity, measured by the release of fluorescent B-naphthylamine was recorded with a fluoromicrophotometer (Corning 7-60 primary filter and a Wratten 2A secondary filter) after incubation for 6 hr at 37 C. Species differentiation of *Colletotrichum* on the basis of aminopeptidase activity was demonstrated. Differences in activity between isolates of the same species were not sufficiently large to permit the separation of isolates into groups which corresponded to isolate sources. The phenomenon of fluorescence quenching was observed and provided an additional parameter for isolate identification.

Introduction

The genus *Colletotrichum* contains a number of economically important fungal plant pathogens commonly observed on vegetable crops in Indiana. Three species of current interest include *Colletotrichum coccodes*, *C. graminicola* and *C. gloeosporioides*.

Colletotrichum coccodes (Berk. and Br.) Taub. frequently is involved in a fruit rot of tomatoes (2, 5) and was recently shown to be involved in a widespread disease of potato, black dot root rot, in Indiana (8). *C. coccodes* is also commonly associated with the brown root rot complex of greenhouse tomatoes (7). *C. graminicola* (Ces.) Wils., the causal agent of sweet and dent corn anthracnose, is a potential threat to corn production in Indiana. *C. graminicola* was involved in a severe epiphytotic of anthracnose on sweet corn in Benton County, Indiana, in mid-August 1972 (9) and reduced yields of several dent corn hybrids in 1975. *C. gloeosporioides* Denz., although of apparently minor importance in Indiana, is an additional incitant of tomato fruit anthracnose (5).

The fluorescent aminopeptidase assay technique was proposed in 1967 by Westley, *et al.* (10) for the identification of species of *Bacillus* and other bacteria. The assay has been shown to provide a rapid, reproducible means of identifying plant pathogenic fungi (4) and plant pathogenic bacteria (6). In studies on plant pathogenic microorganisms using the aminopeptidase assay technique, Huber *et al.* (3) separated isolates of *Pseudomonas phaseolicola* into two races and grouped isolates of *Pseudomonas syringae* into one of three profiles depending on the host of origin. The workers also noted an ability to differentiate between

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Xanthomonas phaseoli and *X. phaseoli* var. *fuscans*. Precise control of inoculum concentration, incubation time, prior growth media, and incubation temperature were shown to increase the accuracy of this technique (6).

The present study was undertaken to determine the potential value of the aminopeptidase assay in the separation of three plant pathogenic species of the genus *Colletotrichum* and to further determine whether distinct differences in aminopeptidase activity existed between isolates of a given species that could be directly related to the host of origin.

Materials and Methods

Stock cultures of *Colletotrichum* originated from the following sources: *Colletotrichum coccodes*—three isolates from Indiana grown potatoes (three separate locations) showing symptoms of black dot root rot, one isolate from infected certified potato seed pieces grown in a neighboring state, one isolate from an infested soil sample, one isolate from the root of an infected tomato plant grown in a greenhouse in England (provided by Dr. J. D. Farley, Ohio State University), two isolates from Ohio grown tomato fruit showing symptoms of tomato anthracnose (provided by Dr. J. D. Farley, Ohio State University), and one isolate from a Maryland grown tomato fruit (provided by Dr. T. Barksdale, USDA, Beltsville, Maryland); *Colletotrichum gloeosporioides*—one isolate from an Indiana grown tomato fruit showing symptoms of anthracnose; *Colletotrichum graminicola*—three isolates from anthracnose infected corn (provided by Dr. R. L. Nicholson, Purdue University). Stock cultures were maintained on potato dextrose agar (PDA) prior to and during the course of this study. The fungal isolates were prepared for assay by culture on a sterile 0.45 μ Millipore filter (Millipore Corp., Bedford, Mass.) overlying the agar medium. Cultures were incubated at 24 C for 7 days with a 16 hr photoperiod light source of 300 foot candles. Fungal mycelium was harvested from filters after 7 days' growth, weighed, and homogenized in 0.05M Tris-HCl buffer pH 8.0 with a final concentration of 0.1 g fungal homogenate per 10 ml buffer. The inoculum homogenate (0.1 ml) was added to 1.9 ml of each of 22 amino-B-naphthylamides (2.5×10^{-5} M in 0.05M Tris-HCl buffer pH 8.0) (Table 1). A series of B-naphthylamines and Tris buffer

TABLE 1. *Beta-Naphthylamide substrates used for analysis of Colletotrichum isolates.*

L-Alanyl (ALA)	L-Lysyl (LYS)
L-Arginyl (ARG)	L-Methionyl (MET)
Benzyl-Arginyl (BANA)	4-Methoxy-L-Leucyl (4M-LEU)
L-alpha-Aspartyl (ASP)	L-Phenylalanyl (PHE)
L-gamma-Glutamyl (GLU)	L-Prolyl (PRO)
Glutamyl-L-Phenylalanyl (GLU-PHE)	L-Pyrolidonyl (PYR)
Glycyl (GLY)	L-Seryl (SER)
L-Histidyl (HIS)	L-Threonyl (THR)
L-Hydroxy-Prolyl (H-PRO)	L-Tryptophyl (TRY)
L-Leucyl (LEU)	L-Tyrosyl (TYR)
L-Isoleucyl (ILEU)	L-Valyl (VAL)

were also inoculated to determine the maximum fluorescence obtainable with complete hydrolysis and background fluorescence, respectively. After incubation for 6 hr at 37 C, aminopeptidase activity was determined fluorometrically by measuring the hydrolyzed B-naphthylamines in an Aminco fluoromicrophotometer equipped with a Corning 7-60 narrow band pass primary filter and a Wratten 47-B narrow band pass secondary filter. Fluorometric readings were corrected for background fluorescence and calculated as a percentage of the 100% relative fluorescence for each substrate. All assays were repeated a minimum of 6 times. Polar graph and bar graph profiles of average percent substrate hydrolysis were constructed for each fungal isolate.

Results

The greatest differences in aminopeptidase activity were generally observed between species of *Colletotrichum*. Small overall differences in activity were generally observed between isolates of the same species. Polar and bar graph profiles of selected isolates are shown in Figs. 1 and 2.

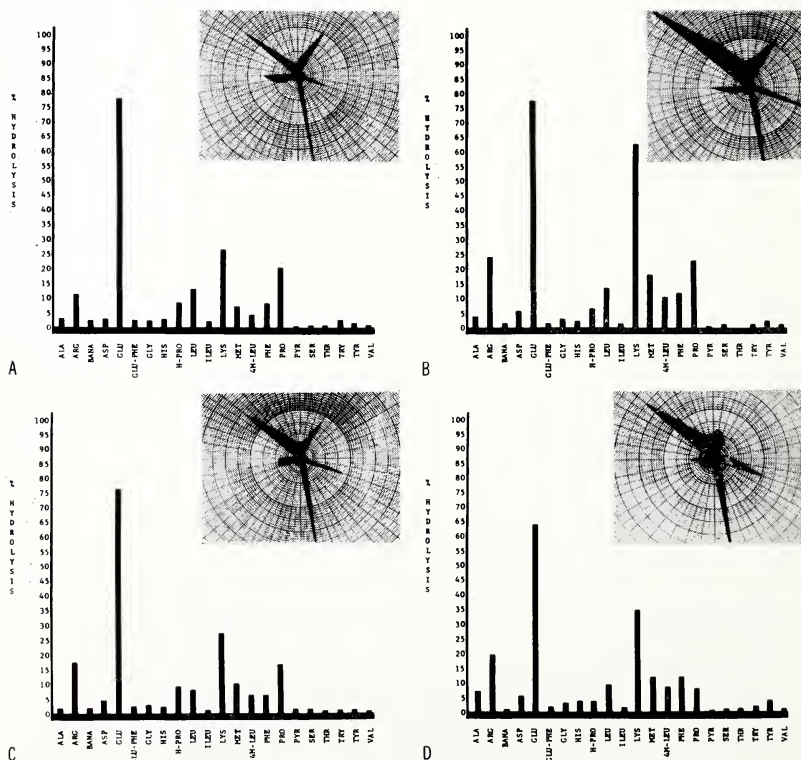


FIGURE 1. Bar and polar graph profiles of aminopeptidase activity of four isolates of *Colletotrichum* coccodes A) 74-1S, Indiana potato stem; B) 75-5S, Certified potato seed piece; C) CA-8, Tomato root; D) T-7, Tomato fruit.

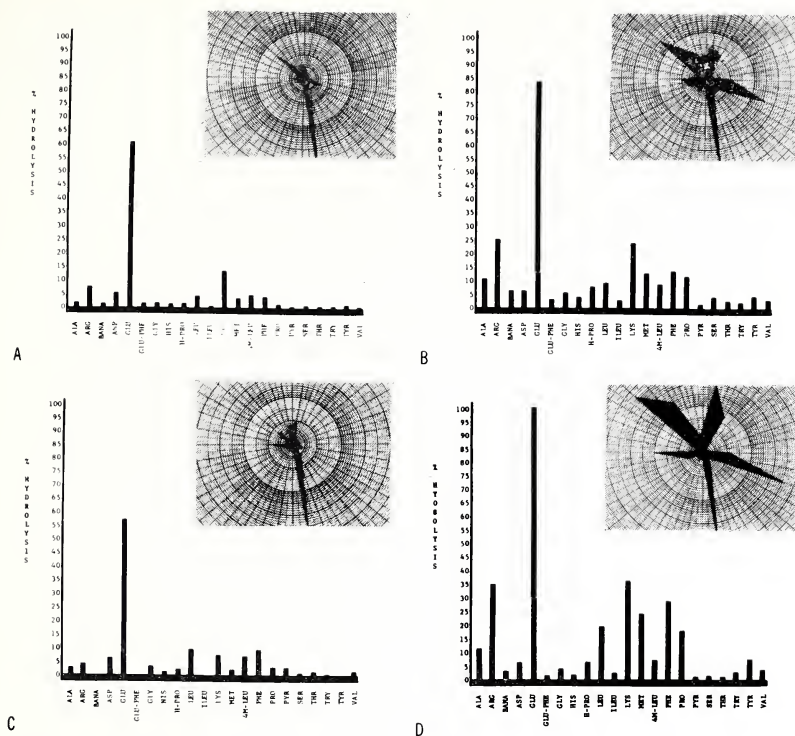


FIGURE 2. Bar and polar graph profiles of aminopeptidase activity of selected isolates of *Colletotrichum* A) CG-103, *C. graminicola* from Indiana dent corn; B) CG-104, *C. graminicola* from Indiana sweet corn; C) CG-105, *C. graminicola* from North Carolina sweet corn; D) CGL-1, *C. gloeosporioides* from Indiana tomato fruit.

C. gloeosporioides appeared to be the most enzymatically active species tested. The percent B-naphthylamine cleaved from amino acids by this species was greater than all isolates tested for the following substrates: alanine, arginine, gamma-glutamine, leucine, methionine, phenylalanine and tyrosine. *C. graminicola*, on the other hand, was generally characterized by low enzyme activity, except for a single Indiana sweet corn isolate which generally showed a higher activity than the other *C. graminicola* isolates for most of the substrates. *C. coccodes* isolates as a group were generally more active than the activity of *C. graminicola*, but less than the activity of *C. gloeosporioides*. A single isolate of *C. coccodes* from certified potato seed stock differed markedly from other isolates of *C. coccodes* by a two-fold increase in the hydrolysis of L-lysyl-beta-naphthylamide.

The phenomenon of fluorescent quenching with incubation was observed with all isolates studied (Table 2) and appeared to provide another parameter for comparison of isolates. The highest quenching was associated with an isolate of *C. coccodes*.

TABLE 2. *Origin and percent fluorescence quenching of Colletotrichum isolates.*

Isolate Code	<i>Colletotrichum</i> sp.	Origin	% Quenching
74-1S	<i>C. coccodes</i>	Indiana — potato stem	67.8
74-2S	<i>C. coccodes</i>	Indiana — potato stem	82.9
74-5S	<i>C. coccodes</i>	Indiana — potato stem	77.0
75-5S	<i>C. coccodes</i>	Certified potato seed piece	82.2
75-16	<i>C. coccodes</i>	Indiana — soil sample	83.9
CA-8	<i>C. coccodes</i>	England — tomato root	61.3
C-9	<i>C. coccodes</i>	Ohio — tomato fruit	95.4
C-13	<i>C. coccodes</i>	Maryland — tomato fruit	83.6
T-7	<i>C. coccodes</i>	Ohio — tomato fruit	90.1
CG-103	<i>C. graminicola</i>	Indiana — dent corn	82.8
CG-104	<i>C. graminicola</i>	Indiana — sweet corn	28.1
CG-105	<i>C. graminicola</i>	North Carolina — sweet corn	84.6
CGL-1	<i>C. gloeosporioides</i>	Indiana — tomato fruit	55.9

Discussion

The fluorometric aminopeptidase assay provides a rapid reproducible method of separating at least three species of the genus *Colletotrichum*. Although single isolates of a given species of *Colletotrichum* were quantitatively different from other isolates of the same species in their hydrolysis of specific naphthylamides, it was not possible to separate the isolates into distinct groups which correspond to their host of origin. Since several isolates were subcultured repeatedly on PDA medium after initial isolation from host tissue, it is conceivable that variability between isolates of the same species may have been affected. Isolate differences observed were comparable to those attributed to prior growth conditions by Westley, et al. (10) and Krawczyk and Huber (6). The relationship of peptidase activity to pathogenesis or host tissue preference would be an interesting extension of this study. Continued natural occurrence of these pathogens should provide an opportunity to evaluate isolate and environmental influences relative to peptidase relationships.

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Production of Xylanases by *Verticillium albo-atrum*¹

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Abstract

A xylan extract from corncobs contained xylose and trace amounts of arabinose, glucose, and an unidentified uronic acid. The xylan was utilized as a carbon source for growth and production of xylanases by *Verticillium albo-atrum* in vitro and as a substrate for xylanase characterization.

An extracellular xylanase system was found in dialyzed, concentrated culture filtrates of *V. albo-atrum*. Optimum xylanase activity occurred in the range of pH 5.0 to 5.5 at 35 to 40 C. Chromatographic analysis of enzymatic hydrolysis products of xylan revealed the presence of xylose, xylobiose, xylotriose, xylotetraose, and trace amounts of glucose and a uronic acid. Heat inactivation of the xylanase system occurred between 61 and 70 C. Xylanase preparations heated to 50 C prior to enzyme-substrate incubation hydrolyzed xylan to xylose and xylobiose. Although reducing group liberation was observed in enzyme-substrate mixtures where the enzyme was heated to 60 C prior to incubation, no chromatographically detectable hydrolysis products were observed in the mixtures.

The results suggested that at least three xylanases were synthesized by *V. albo-atrum*. One appeared to liberate single xylcse units and a second appeared to hydrolyze xylan to xylobiose residues. Xylooligosaccharides in reaction mixtures suggested the presence of an endoxylanase.

Introduction

Verticillium albo-atrum Reinke and Berth. is the causal agent of *Verticillium* wilt of tomato and potato. The disease exhibits the three typical phases of development of a wilt syndrome (18). The pathogen penetrates the host roots and is confined to the xylem during early stages of the disease cycle. As the disease progresses, irreversible symptoms of stunt, chlorosis, epinasty, and wilt occur. As the host dies, the pathogen spreads throughout the tissue and eventually sporulates.

Hancock and Millar (8) suggested that the action of xylanases and other hemicellulases would allow a pathogen to spread throughout the host by the enzymatic removal of non-structural wall polymers associated with lignins and cellulosic materials. The products of degradation of such cell wall components might also serve as a readily accessible carbohydrate source, aiding the continued proliferation of the pathogen.

The chemical constitution of xylans indicates a wide variety of structures and molecular weights, and each plant species may have one or more characteristic xylans with molecular weights ranging from 7,000 to 30,000 (2, 5, 6, 11, 16). Studies of the enzymatic hydrolysis of xylans are limited by a lack of information concerning xylan and its

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relative importance to the integrity of the cell wall. Extracellular xylanases are classified according to the manner of hydrolysis of xylan. The nomenclature is similar to that applied to enzymes that hydrolyze pectic substances (3). A xylanase that hydrolyzes the xylan chain by random cleavage is designated an endoxylanase. This term is also applied to xylanases that cleave xylooligosaccharides into smaller oligomers but not specifically to D-xylose. Exoxylanases remove single xylose units from xylan chains or oligomers. The objective of this research was to determine whether the wilt pathogen *V. albo-atrum* is capable of utilizing xylan as a carbon source and to partially characterize the xylanases produced.

Methods and Materials

Extraction of xylan.—Extraction and purification of xylan was by the method of Adams (1) using corncobs dried at 120 F and ground in a Wiley Mill (3 mm screen). The extract was acid hydrolyzed by a modification of the method of Sørensen (13). Ten ml of a 1% solution was mixed with 40 ml of 1.25 N H_2SO_4 and refluxed for 12 hours. The hydrolysate was cooled and the volume brought to 100 ml with deionized water.

A saturated solution of $\text{Ba}(\text{OH})_2$ was added until precipitation was complete. The precipitate was removed by centrifugation at 10,400 *g* for 20 minutes. The supernate was recovered and a solution of 5.0 percent ZnSO_4 was added to precipitate excess barium and reduce the quantity of barium salts of uronic acids. The precipitate was again removed by centrifugation, toluene was added (1 ml/1) and the supernate was placed in dialysis tubing and reduced to one-half volume by pervaporation. The concentrated hydrolysate was chromatographed on Whatman No. 4 paper in amounts of 50, 100, 150, 200 and 250 μl . Chromatograms were developed by descending chromatography. Solvent systems were ethyl acetate-acetic acid-water (9:2:2 v/v) or n-butanol-pyridine-water (10:3:3 v/v) (13).

After the solvent had traveled 47 cm, the chromatograms were dried and sprayed with a freshly prepared solution of equal volumes of 1.8% aniline in absolute ethanol and 1.8% oxalic acid in water and dried at 95-100 C for 10 minutes (10). By this procedure pentoses appeared red, hexoses brown, and uronic acids yellow.

Culture of Verticillium albo-atrum.—An isolate of *V. albo-atrum*, pathogenic to potatoes and tomatoes was maintained on potato-dextrose agar and grown in liquid shake culture in 500 ml flasks (100 rpm, 22 C) for induction of xylanase enzymes. The liquid medium contained 1% (w/v) xylan and the following salts per liter: 5.0 g NH_4NO_3 , 2.5 g KH_2PO_4 , 0.5 g MgSO_4 , 0.01 g ZnSO_4 , and 0.06 g FeCl_3 (final pH 5.0). After 6 days the contents of each flask were filtered through cheese-cloth, centrifuged for 20 minutes at 10,400 *g*, and the supernate was collected and filtered through a 0.22 μ Millipore filter (Millipore Filter Corp., Bedford, Mass.). Toluene (1 ml/1) was added to prevent contamination and the filtrate was dialyzed against deionized water for 12 hours. The filtrate was reduced to one-half the original volume with

Carbowax 4000, removed from dialysis tubing and checked for contamination by plating aliquots on potato dextrose and nutrient agar. Toluene (1 ml/1) was added and the preparation was frozen until used for enzyme assays.

Determination of xylanase activity:—Xylanase activity was measured by reducing group liberation from xylan. Reaction mixtures consisted of 3 ml culture filtrate and 11 ml 2% xylan in 0.1 M sodium acetate-acetic acid buffer. Reaction mixtures were buffered at pH 4.0, 4.5, 5.0, 5.5, 5.8 and 6.5 and incubated at 25, 30, 35, and 40 C for determination of pH and temperature optima.

At intervals throughout incubation, 1.0 ml aliquots of enzyme-substrate mixtures were assayed for reducing group liberation by the method of Somogyi (12) using Nelson's (9) arsenomolybdate color developer. Samples were filtered through an 8 μ Millipore filter and optical density was determined at 520 nm. Xylanase activity was expressed as μ M of xylose liberated/ml enzyme preparation. Reducing group measurements taken immediately after the addition of enzyme to substrate served as controls and were subtracted from all other readings to account for residual reducing groups.

Determination of inactivation temperature of the xylanase system:—The enzyme preparation was incubated for one hour at 50, 60, 70, or 80 C. After incubation, 1.5 ml aliquots were mixed with 5.5 ml xylan substrate buffered as previously described. Reaction mixtures were incubated at 35 C and at one, two and five hours after the start of incubation, 1.0 ml aliquots were removed and reducing capacities were determined. Controls were prepared similarly except that the enzyme preparation was inactivated by autoclaving for 30 minutes. Enzyme-substrate mixtures incubated for 20 hours were used for analysis of hydrolysis products by paper chromatography.

Xylanase assay by paper chromatography:—Xylanase activity was determined chromatographically by observing breakdown products of xylan at various pH and temperature values and at predetermined intervals during incubation. One hundred μ l aliquots were chromatographed on Whatman No. 4 paper. Chromatograms were developed at room temperature using a descending solvent of n-butanol-acetic acid-water (8:2:5 v/v) and were dried and sprayed with aniline-oxalic acid reagent for color development. The presence of xylooligosaccharides was determined by graphing R_m values [$\log (1/R-1)$] of successive spots against the number of xylose residues in a series of xylose oligomers (4).

Results

Xylan extract:—The presence of pentoses in the corncob extract was confirmed by a positive aniline acetate test for pentoses (15). Chromatographic analysis of the extract hydrolysate demonstrated the presence of two pentoses, a hexose and a uronic acid (Table 1). The pentoses had R_f values which corresponded to reference standards of xylose and arabinose and the hexose R_f corresponded to that of glucose. The uronic

TABLE 1. *Chromatographic analysis of products of acid hydrolysis of the corn cob xylan extract.*

Solvent : n-butanol-pyridine-water (10:3:3 v/v)		Solvent : ethyl acetate-acetic acid-water (9:2:2 v/v)	
Hydrolysis products	R _f	Hydrolysis products	R _f
pentose	0.570	pentose	0.702
pentose	0.462	hexose	0.622
hexose	0.338	uronic acid	0.505
Reference standards		Reference standards	
xylose	0.576	xylose	0.694
arabinose	0.465	arabinose	0.684
glucose	0.353	glucose	0.624

acid was not identified. Both the hexose and the uronic acid were only present in trace amounts.

Optimum temperature and pH for xylanase activity.—Optimum temperature and pH for xylanase activity was determined by reducing group assay of aliquots of each enzyme-substrate mixture sampled at 2, 4, 6, 8, 10, and 12 hours after enzyme-substrate incubation. After 12 hours incubation, the optimum activity for each pH was observed at 35 C except at pH 5.8 and 6.5 where optimum activity occurred at 40 C (Table 2). Maximum reducing group liberation was observed in enzyme-substrate mixtures incubated at 35 C and pH 5.5 and this combination was considered close to the optimum for the xylanase preparation.

Enzyme-substrate mixtures at pH 4.0 exhibited the least reducing group liberation at all temperatures studied (Table 2). The least activity was observed at 25 C for each pH studied. A marked decrease in enzyme activity of mixtures incubated at 35 C occurred when the pH was changed from 5.5 to 5.8 (Table 2, Fig. 1 and 2). However, activity of mixtures incubated at 40 C only decreased slightly from pH 5.5 to 5.8. The sharp decrease in activity from pH 5.5 to 5.8 observed in mixtures incubated at 35 C suggested inhibition of activity

TABLE 2. *Optimum temperature and pH for xylanase activity as determined by reducing group assay.*

pH	Temperature (centigrade)			
	25	30	35	40
4.0	4.43 ¹	3.08	4.63	2.08
4.5	7.75	9.96	12.52	10.96
5.0	7.80	9.64	13.46	13.46
5.5	8.09	9.96	14.08	12.94
5.8	6.84	10.20	10.05	12.44
6.5	5.91	6.61	6.50	7.16

¹Values presented are for μM xylose equivalents liberated per ml enzyme after twelve hours incubation and represent the average of six replicates per treatment. Reducing capacity of samples taken immediately after the addition of enzyme to substrate served as controls and were subtracted from all other readings to account for residual reducing groups.

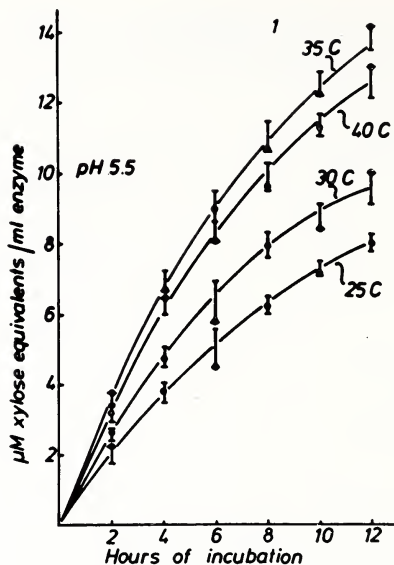


FIGURE 1. Effect of temperature on xylanase activity in reaction mixtures buffered at pH 5.5.

of an enzyme(s) sensitive to pH above 5.5. The same change in pH resulting in a decrease in activity of mixtures at 35 C could bring about an increase in activity of a second enzyme component. This would account for the observation of greater reducing activity of mixtures incubated at 40 C and pH 5.8 over those at 35 C and pH 5.8 (Fig. 2). *Chromatography of products of enzymatic hydrolysis of xylan*:—Enzyme-substrate mixtures used in determination of optimum temperature and pH were incubated for 36 hours at 25, 30, 35, or 40 C. After incubation, 100 μ l of each mixture were chromatographed and developed as previously described, using a descending solvent system of n-butanol-acetic acid-water (8:2:5 v/v).

Pentose oligomers, indicated by red spots, were the major products of hydrolysis. A linear relationship between the R_m values (4) and the number of repeating units in successive oligomers was observed (Fig. 3), indicating that the spots represented a series of xylooligosaccharides. By this method the R_f of xylose was calculated to be 0.441. The R_f values of xylose oligomers were: xylobiose, 0.337; xylotriose, 0.243; and xylotetraose, 0.168. Streaked areas of partially hydrolyzed substrate extended from the point of application of each enzyme-substrate mixture indicating the presence of oligomers of more than four xylose units. This suggested the presence of an endoxylanase that randomly hydrolyzed the xylan polymer.

Trace levels of a hexose and a uronic acid were observed on some chromatograms. The hexose was found between xylose and xylobiose and the uronic acid between xylotriose and xylotetraose. R_f values for the hexose and glucose were identical. The uronic acid was unidentified.

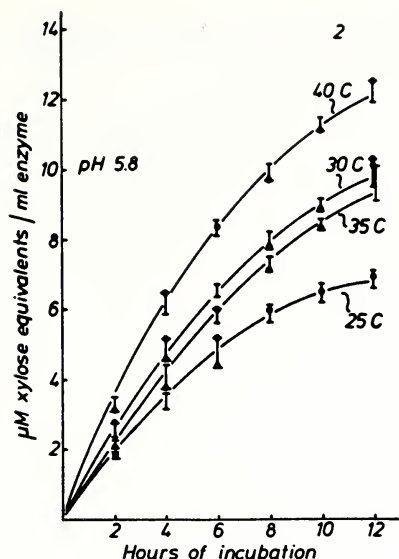


FIGURE 2. Effect of temperature on xylanase activity in reaction mixtures buffered at pH 5.8.

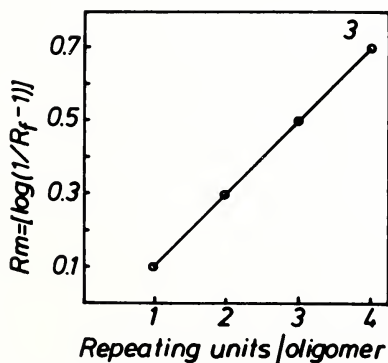


FIGURE 3. Relation of R_m value to the number of xylose units per oligomer.

The amount of each hydrolysis product appearing on chromatograms was estimated visually (Table 3). The greatest number of hydrolysis products was observed in mixtures incubated at 35 C and pH 5.0 to 5.5, suggesting that these conditions were optimum for hydrolytic activity of the xylanase system. The least amount of hydrolysis products was observed in mixtures at pH 4.0 at all temperatures.

The absence of xylose and the presence of xylose oligomers in mixtures incubated at 40 C and pH 6.5 suggested inactivation of a xylanase specific for the hydrolysis of single xylose units from xylose oligomers.

TABLE 3. *Chromatographic analysis of enzymatic hydrolysis products of xylan suspensions at six different pH values incubated at four temperatures for 36 hours.*

Conditions of hydrolysis		Hydrolysis products ¹					
Temperature	pH	xylose	xylo- biose	xylo- triose	xylo- tetraose	glu- cose	uronic acid
25 C	4.0	1	1	0	0	1	0
	4.5	2	2	1	0	1	1
	5.0	2	2	1	1	1	1
	5.5	3	2	2	1	1	1
	5.8	2	2	2	1	1	1
	6.5	1	2	1	0	1	0
30 C	4.0	1	1	1	0	1	0
	4.5	2	2	2	0	2	0
	5.0	2	3	2	1	2	1
	5.5	3	3	3	1	2	1
	5.8	3	3	3	1	1	1
	6.5	1	2	2	1	1	1
35 C	4.0	1	1	1	0	1	0
	4.5	3	2	1	1	2	0
	5.0	3	4	3	2	2	1
	5.5	3	4	3	2	2	1
	5.8	3	3	3	1	1	1
	6.5	1	2	3	1	1	0
40 C	4.0	1	1	0	0	1	0
	4.5	2	2	2	0	2	1
	5.0	3	2	2	1	2	0
	5.5	3	3	2	1	2	1
	5.8	3	3	2	1	1	1
	6.5	0	3	3	1	1	0

¹The quantity of each hydrolysis product was visually rated according to the following scale: 0=none, 1=trace, 2=slight, 3=moderate, 4=heavy.

Heat inactivation of the xylanase system:—Heating the enzyme preparation at 70 C for 1 hour resulted in complete loss of detectable enzyme activity as measured by reducing group liberation and chromatographic analysis. When the enzyme preparation was heated to 50 C an increase in reducing group liberation over the control series was readily apparent; however, only a slight increase in reducing groups was observed in enzyme-substrate mixtures where the enzyme was preheated to 60 C (Table 4). After five hours incubation, reducing activity was highest in enzyme-substrate mixtures buffered at pH 5.5 and lowest in mixtures buffered at pH 4.0 (Table 4).

Chromatographic analysis demonstrated faintly detectable hydrolysis products in mixtures incubated at 50 C. A pentose with an R_f identical to that of D-xylose was present in each mixture except those buffered at pH 6.5. A pentose with an R_f similar to that calculated for xylobiose was present only in enzyme-substrate mixtures buffered at pH 5.8 and 6.5. This suggested that an enzyme(s) capable of hydrolyzing xylan to xylose and xylobiose was present. Liberation of reducing groups by preparations heated to 60 C indicated that the enzyme preparation was not inactivated but the absence of chromatographically detectable hydrolysis products suggested either that hydrolysis products were

TABLE 4. Reducing group liberation from corncob xylan by enzyme preparations preheated at 50, 60 and 70 C for 1-hour.

pH ¹	Heat Treatment		
	50 C	60 C	70 C
4.0	3.25 ²	3.00	0.00
5.5	5.15	3.80	0.00
5.8	4.45	3.50	0.00
6.5	4.30	3.30	0.00

¹pH of enzyme-substrate reaction mixture. Reaction mixtures were incubated at 35 C and consisted of 5.5 ml 2% xylan in 0.1 M acetate buffer and 1.5 ml enzyme preparation.

²Values are the average of six replications and are expressed as μ M D-xylose equivalents liberated/5 hr/ml enzyme preparation

present in undetectable concentrations or that they were not liberated from the xylan polymer.

Discussion

The xylan utilized in this study was extracted from corncobs by the method of Adams (1). Acid hydrolysis and chromatography of the xylan indicated the presence of xylose, arabinose, glucose, and an unidentified uronic acid. Arabinose, glucose and the uronic acid were present in relatively low levels as compared to xylose. Therefore, components found in the corn cob xylan of this study compared favorably with those previously reported (1, 2, 5, 16).

Extracellular xylanases of fungi previously investigated have exhibited optimum activity in the range of pH 3.4 to 7.5 and 30 to 50 C (7, 13, 14, 17). The xylanase system of *V. albo-atrum* exhibited optimum activity at 35 C and pH 5.5 for the temperature and pH combinations studied.

Inactivation of the xylanase system was measured by reducing group assay and paper chromatography. Reducing group liberation was not detected in enzyme-substrate mixtures where the enzyme preparation was heated for one hour at 70 C. However, enzyme preparations heated at 50 and 60 C retained some activity.

Chromatography of enzyme-substrate mixtures revealed that no products of hydrolysis could be detected in mixtures where the enzyme was heated to 60 C or above. However, an increase in reducing group liberation observed with preparations heated at 60 C indicated that some hydrolysis occurred. The hydrolysis products were either too large or too few for detection by chromatography.

Chromatography of enzyme-substrate mixtures where the enzyme was previously heated to 50 C revealed the presence of xylose in mixtures buffered at pH 5.0, 5.5, and 5.8. Xylobiose was present in mixtures buffered at pH 5.8 and 6.5. These results may indicate a suppression of xylanase activity at pH 6.5 assuming that the substrate was hydrolyzed to xylobiose prior to hydrolysis to xylose. However, these data may also indicate the presence of more than one xylanase in the enzyme preparation. The absence of xylose in mixtures buffered

at pH 6.5 may indicate the inactivation of an enzyme that liberated single xylose units from the substrate. The presence of xylobiose in mixtures buffered at pH 5.8 and 6.5 may indicate the presence of an enzyme that cleaved the substrate to xylobiose.

Chromatography of hydrolysis products of enzyme-substrate mixtures used in optimum temperature and pH studies also suggested the presence of more than one enzyme. Xylose and xylobiose were present in relatively large quantities in hydrolysates at optimum temperature and pH (35 C and pH 5.5, Table 3). However, at 35 C and pH 6.5 the amount of xylose present had decreased whereas xylobiose was still present in substantial quantity. The absence of xylose in mixtures incubated at 40 C and pH 6.5 and the increase of xylobiose over the levels in mixtures at the same pH and lower temperatures suggested that the absence of xylose in mixtures incubated at 40 C and pH 6.5 resulted from inactivation of a xylanase that liberated single xylose units from the substrate. The presence of xylotriose, xylotetraose, and larger xylose oligomers indicated the presence of an endoxylanase that randomly hydrolyzed the polymer.

Strobel (14) proposed that when corn cob xylan was utilized by *Diplodia viticola*, an enzyme was produced that released single unit branches of arabinose from the main chain. Sørensen (13) observed both arabinose and xylose-arabinose oligosaccharides in enzyme hydrolysates of xylan. Although arabinose was found to be present in the corn cob xylan used in this investigation, it was not observed as a product of enzymatic hydrolysis. This indicated that *V. albo-atrum* did not produce an arabinose specific enzyme under conditions of this study.

The presence of glucose in enzyme hydrolysates of this study suggests the possibility that *V. albo-atrum* produced an enzyme that released glucose from the main xylan chain or that glucose was removed by a xylanase that could not differentiate between the β -(1-4) glycosidic linkage of repeating xylose units and that attaching glucose to xylose.

Since xylans and other hemicelluloses are found associated with cell walls of higher plants (2, 6, 11), these constituents may be dissolved by extracellular hemicellulases of *V. albo-atrum*. Such enzymatic activity may be important to the final stage of the wilt disease syndrome since hydrolysis of xylans could facilitate passage of the fungus through the moribund plant and furnish the fungus with a carbon source.

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PHYSICS

Chairman: RICHARD L. CONKLIN,
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ROBERT E. HALE, Huntington College,
Huntington, Indiana 46750
was elected Chairman for 1976

ABSTRACTS

A Versatile Biopotential Amplifier Utilizing High-Performance Integrated Circuits. WM. BENTLY, CTS Corporation, Elkhart, IN 46514, JERRY NISBET and EDWIN C. CRAIG, Department of Physics and Astronomy, Ball State University, Muncie, Indiana 47306.—The widespread use of electronic measurement systems in biological and medical laboratories has brought about the need for simple signal conditioning systems which can be used in college laboratories to familiarize students of the life sciences with the basic principles of electronic measurement methods. This paper describes a simple circuit featuring adjustable gain and bandwidth, which can be used to amplify the EEG, EKG or EMG of small animals for display on an oscilloscope or chart recorder. Since it possesses low-noise and low-drift, it can also be used with low level transducers. High accuracy and reliability are obtained through the use of premium integrated circuits offering performance levels previously obtainable only in discrete circuits. The performance of an FET OP AMP input stage is compared to the performance of an input stage using matched bipolar OP AMPS. This general purpose instrument should find wide applicability in both the research lab and classroom.

Physics, the Mind, the Body and the EEG. DARRYL L. STEINERT, Department of Physics, Hanover College, Hanover, Indiana 47243.—Recent research in biofeedback training has found that there are correlates between the electroencephalographic (EEG) activity and emotional and physiological functioning. These correlates range from, for the EEG, broad bandwidth EEG signals with broadly defined terms such as relaxed attentiveness or deep sleep, to correlates between 40 hertz EEG components and problem-solving such as doing multiplication mentally and correlates between 12-14 hertz signals from the sensorimotor cortex and epileptic seizure rates. Since physicists have a long tradition of signal seeking and deciphering, I thought that this research should be brought to their attention.

A Comparison of Patterns of Sulfur Dioxide Concentrations over Anderson, Indiana Determined with Huey Sulfation Plates with those Generated by a Gaussian Plume Diffusion Model.¹ RONALD J. LOSURE*, Taylor University, Upland, Indiana 46989, ROBERT HAZEN, RICHARD OLDHAM, and CHARLES W. MILLER, Department of Physics, Anderson

*Presenter.

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College, Anderson, Indiana 46011.—Results of a simulation of sulfur dioxide concentrations with a Gaussian diffusion model correspond well with those measure in July 1974 with Huey sulfation plates. The model shows that under wind conditions similar to those of July 1974 some areas of Anderson, Indiana can expect to have consistently high concentrations of SO_2 . The model also shows that under certain atmospheric conditions, these same areas may experience extremely high concentrations.

A Sulfur Dioxide Survey for Anderson, Indiana.¹ RONALD J. LOSURE, Taylor University, Upland, Indiana 46989, ROBERT HAZEN, RICHARD OLDHAM*, and CHARLES W. MILLER, Department of Physics, Anderson College, Anderson, Indiana 46011.—During July 1975 a thirty-day survey of the sulfur dioxide content of the atmosphere over Anderson, Indiana was conducted. This is a continuation of a project begun in 1974. Huey sulfation plates were exposed at 40 sites over the city during the study. The results of the survey indicate that the level of sulfur dioxide pollution has decreased significantly from the previous year. However, the decrease may be partially due to unusual weather conditions and thus may be temporary.

A Comparison of Sulfur Dioxide Methods: Pararosaniline Method and Huey Sulfation Plates in Anderson, Indiana.¹ BOB HAZEN*, DICK OLDHAM, Anderson College, Anderson, Indiana and RON LOSURE, Taylor University, Upland, Indiana and CHARLES W. MILLER, Department of Physics, Anderson College, Anderson, Indiana 46011.—Thirty-day Huey sulfation plates were exposed at 40 sites covering the Anderson city limits during the summer of 1975 to monitor the sulfur dioxide content of the air. For a check on the plate efficiency the pararosaniline method of SO_2 detection was used at the Anderson College plate site. From the results of nine sampling dates the pararosaniline method preformed relatively consistent. The mean for the pararosaniline method was 0.006 ppm for the 30 days and the mean of the plates was 0.007 ppm.

Photographic Study of the Lunar Eclipse of May 24-25, 1975. MALCOM E. HULTS, Department of Physics and Astronomy, Ball State University, Muncie, Indiana 47306.—Time-lapse photography was attempted with the partial phases of the lunar eclipse of May 24-25, 1975. The sequence of shots was as follows: one picture every eight seconds of the partial phase before totality, approximately 10 seconds in "real time" taken of totality, one picture every eight seconds of the partial phase after totality, and approximately 10 seconds in "real time" of the full moon immediately after totality. Visual aids were photographed on the same film and the result was processed into a film loop to be used for instructional purposes.

Photometric Observations of the Star Cluster NGC2141. R. D. BURGESS, Department of Physics and Astronomy, Ball State University, Muncie,

*Presenter

¹This work was supported by the National Science Foundation through its Undergraduate Research Participation program, grant EPP 75-04449.

Indiana 47306.—Photoelectric and photographic observations are presented for the open cluster NGC2141. The data indicate the cluster is of late intermediate age with a main-sequence turn off at $M_v = 3.5$, $(B-V) = 0.40$. A mean color excess of $E_{(B-V)} = 0.30$ and a distance modulus of $m - M = 14.1$ yield ($R=3.0$) a distance of 4.4 kpc.

Acceleration of Gravity Equation. HARRY A. MONEYHUN, 1226 E 18th St., Anderson, Ind. 46016.—Because the acceleration of gravity refers to the acceleration of a secondary relative to a primary, the acceleration of both the secondary and the primary must be calculated for an exact and correct answer. Since the sum of the masses represent the total energy of a two body system, the sum of the masses must be included in the equation for the acceleration due to gravity. The corrected equation is $g = G(M+m)/s^2$.

Investigation of Low Temperature Anomalies in Specific Heat in Irradiated Glassy Carbons. ERIC MICHAEL and BRUCE MYERS, Department of Physics and Astronomy, Ball State University, Muncie, Indiana 47306.—Investigations of neutron irradiated glassy carbons have been carried out below 4.5°K by S. Mrozowski, A. Vagh, et al. Striking anomalies were found. These anomalies extend to and probably far above 4.5°K making investigation of the specific heat above this temperature imperative. To this end apparatus was constructed to measure specific heat of solids from 4.2°K to room temperature. To check the operation of the apparatus preliminary measurements were made at liquid nitrogen temperature. No dependence of specific heat on neutron irradiation was found at this point. Thus further investigation will be concentrated in the range from liquid helium to liquid nitrogen temperature.

General Honors 202—Modern Science A Sophomore General Education Course In Modern Science. L. GENE POORMAN, Professor of Physics, Indiana State University, Terre Haute, Indiana 47809.—This author is teaching a course for sophomores at ISU pre-selected to enroll in the Honors Program by virtue of high academic achievement and College Board scores. The paper deals with content, method, and evaluation of the general honors 202 course. Topical outlines, bibliographies, examples of student interaction constitute the discussion relating to content, method and evaluation.

On the Mobius Transformation and Relativity. W. KRABACHER, Department of Mathematics, Indiana University, Bloomington, Indiana and T. ALVAGER, Department of Physics, Indiana State University, Terre Haute, Indiana 47809.—The Mobius transformation is known to be the most general transformation that can be obtained from the basic, single assumption that the speed of light is constant in all inertial frames. In this study the time-dilation, the equivalent of relativistic mass and other "relativistic" quantities have been derived from the Mobius transformation and confronted with experimental data to test the applicability of the transformation. Of interest has also been a study of the possibility of incorporating the idea of faster-than-light particles into the general framework of the Mobius transformation.

On a Theorem of Eisenhart and Its Importance for Solutions of Schrödinger's Equation. HERBERT H. SNYDER, Department of Mathematics, Southern Illinois University, Carbondale, IL 62901.—The one-particle Schrödinger equation may be solved by separation of variables only in certain coordinate systems, and then only for certain forms of the potential. In a 1948 paper which appears to have been rather neglected, L. P. Eisenhart enumerated those coordinate systems and gave for each the explicit structure of the potential (cf. *Phys. Rev.* 24, 87-89). In the present paper, the author sets forth those systems enumerated in Eisenhart's theorem which seem most useful, and obtains in each case the ordinary differential equations which result upon separation of variables. These equations are discussed for some of the better-known coordinate systems, and some questions of explicit and/or approximate solvability are taken up for certain forms of the potential. The aim of the work is to increase the number of solvable cases of Schrödinger's equation which have physical interest.

Analysis of Grass Samples for Lead Content by X-Ray Fluorescence

D. KLOPFENSTEIN and E. NUSSBAUM

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X-ray fluorescence is a well known technique for fast, non-destructive, multielement, qualitative analysis. More recently this technique is being used in quantitative work. Its virtues in such applications make it a very useful analytical tool. This paper describes a technique in which X-ray fluorescence can be calibrated with atomic absorption spectrometry and thereby quantified. Specifically, it deals with lead concentrations in grass samples along interstate highways. The report emphasizes the technique that has been developed. Data which have been acquired are not exhaustive but show the potential inherent in the procedure.

Procedure

Grass samples were collected from along I-69 between Upland and Fort Wayne and from I-294 near Chicago. These samples were prepared in two ways: the "cup" method, and the "planchet" method. The cup method is the simpler and quicker procedure. It involves cutting the grass into lengths from 1-2 cm. After drying the sample in a desiccator 1.50 grams are weighed into a Dixie medicine cup. The 30 ml cup is covered with a piece of thin mylar plastic and the sample is ready for counting with the X-ray fluorescence spectrometer.

The planchet method entails more work and a correspondingly longer preparation time. It involves freeze-drying the grass with liquid nitrogen. The grass is cut into 1 cm. lengths. It is placed in a mortar and liquid nitrogen is applied. Upon freezing, the grass can be ground with a pestle and placed in an oven to dry. A constant weight can then be placed in small planchets. The planchet is also sealed with mylar film and the sample is ready to be counted. The advantage of using thin mylar film is that it causes very little attenuation of the X-rays thus allowing for better counting efficiencies.

In both methods of preparation the samples were counted for 80 minutes with a 400 channel analyzer. A blank which contained no grass was also prepared and counted in the same manner as the samples.

After counting, both the lead alpha and lead beta peaks were integrated for each sample. The background count of the blank was also integrated and subtracted from the peak integral thus giving a net peak integral for each sample. Table 1 shows the results obtained by both methods and lists the corresponding lead concentration in parts per million.

In order to quantify the X-ray fluorescence technique a calibration was made using atomic absorption spectrometry (A.A.). Each sample of grass was also analyzed for lead content with A.A. The grass was cut into small pieces and 0.300 grams were weighed and placed in a

TABLE 1. *Lead concentration in grass samples prepared by the cup and planchet methods.*

Sample Number	Cup Method		Planchet Method		Lead Concentration (ppm)
	Alpha Peak Integral	Beta Peak Integral	Alpha Peak Integral	Beta Peak Integral	
2	3161	3039	791	704	333
5	1914	1961	---	---	150
6	2637	2593	452	396	167
11	4205	4309	986	865	433
13	8122	8430	2203	2085	1100

beaker. Ten ml. of concentrated nitric acid was added and the grass was digested for 24 hours. It was assumed here that all the lead in the sample went into solution as lead nitrate even though some fibrous grass material did not dissolve. The organic residue is filtered out and the filtrate is diluted to 100 ml. It is essential to dilute the dissolved samples so that the lead concentration does not exceed the spectrometer's linear working range for lead which is up to 20 ppm.

Lead standard solutions are prepared using the methods described in "Standard Conditions for Lead" (1). The A.A. spectrometer is first calibrated with these standard solutions and then the samples are analyzed. The lead concentrations can then be expressed as parts of lead per million parts of grass. These concentrations are shown in Table 1 for five typical samples.

Results

A graph can now be plotted of net peak integral counts (obtained by X-ray fluorescence) versus lead concentration in ppm (obtained with the A.A. spectrometer). This was done for the data collected with each of the two X-ray methods. The cup method yielded considerable variation between results based on the alpha and the beta peak integrals. There appeared to be no general pattern, and the variation can most probably be attributed to matrix inconsistencies from one sample to another. Figure 1 presents the graphical data obtained by the cup method. In the planchet method the peak integrals were much more consistent with the alpha peak integrals always being greater than the betas. Parallel straight lines can be drawn through the data points for both the alpha and the beta integrals as shown in Figure 2. This confirms that a much more consistent sample was obtained in the planchet method which relies on the freeze-drying technique.

Conclusions

X-ray fluorescence can be used quantitatively for the analysis of heavy metals in grass samples and in other vegetation if the instrument is calibrated with another method such as atomic absorption spectrometry. Once calibration curves are plotted, one has a quick and effective method of quantitative determination. If speed is a major consideration the cup method may be useful since it allows for rapid sample preparation. The lead concentration cannot be determined as accurately, but

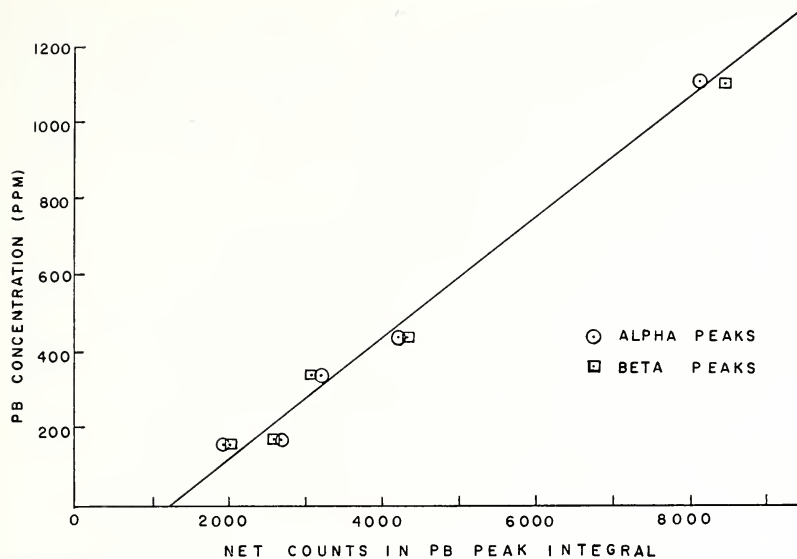


FIGURE 1. Lead concentration in grass samples. Data obtained by X-ray fluorescence using the cup method.

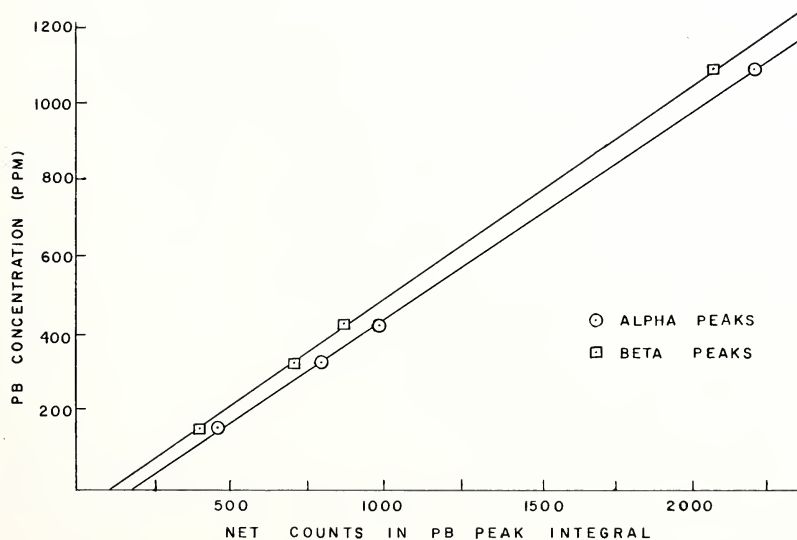


FIGURE 2. Lead concentration in grass samples. Data obtained by X-ray fluorescence using the planchet method.

a general range of concentrations can be obtained, which in many analyses is sufficient. If more accuracy is desired the planchet method, which utilizes freeze-drying, can be used with either the alpha or beta integral peak plot, or both peaks can be used as a check of results. Sample preparation is slightly more involved, but results are greatly improved. Both methods, however, are much quicker than other routine analytical chemistry techniques.

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Nanosecond Fluorescence Study of Chloroplast Systems¹

TORSTEN ALVAGER, J. A. GROSS, and RAYMOND MAGYAR²

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Indiana State University, Terre Haute, Indiana

Abstract

Quinacrine has been employed as a fluorescent probe to study the energized state in chloroplasts by nanosecond fluorescent spectroscopy methods. The fluorescent decay curve of quinacrine consists of two components of lifetimes 4.2 ns and 9.5 ns, respectively. It was found that the well-known decrease in fluorescence intensity of quinacrine in chloroplasts upon irradiation with saturating light was due to a combination of two effects: a decrease in fluorescence intensity of the longlived component without change in lifetime and a change in lifetime of the shortlived component. A comparison of quinacrine fluorescence decay in various pH environments indicated that light-induced changes in pH values of the chloroplast system as a result of proton pumping, is probably not the cause of the observed differences in the quinacrine fluorescence decay curves. Other interpretations will be discussed.

Introduction

In both photosynthetic and respiratory organelles the electron transport system gives rise to the synthesis of energy storage units in the form of adenosine triphosphate (ATP). In the most accepted model of the process, the chemiosmotic model (8), it is assumed that the electron transport process creates a pH differential between the inside and outside of the organelle membrane and that this H^+ -gradient drives the synthesis of ATP. Although the detailed mechanism of the coupling of the two processes has been the subject of extensive investigations over the past twenty-five years it has not given rise to any conclusive answers about the nature of the coupling. However, in the photosynthetic system, the classic experiment of Jagendorf and Uribe (5) has clearly shown that the H^+ -ion gradient artificially induced in the dark can be used as the driving force for ATP production when the chloroplasts are transferred from acidic to basic conditions, still in the dark. That the rate of ATP formation in energized chloroplasts returned to the dark is inversely temperature-dependent has been demonstrated by Kraayenhof et al. (7). In general, the term, "energized state," can be used to symbolize the unknown factors involved in the coupling.

Among the several methods used to investigate the energized state is the technique of incorporating into the system under study a fluorescent probe, such as quinacrine (QC), which uncouples the electron transport system and the synthesis of ATP (9). Changes in the fluorescent output can then be used to monitor the energized state. In the case of QC it is known (6) that the fluorescence intensity decreases when the electron transport system is activated, e.g. by light exposure of a chloroplast system. For this reason, QC is considered a probe of

¹ Supported in part by a small grant from the I.S.U. Research Committee to one of us (T.A.).

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the state of energization of the membrane. However, this interpretation is not unchallenged. It has been suggested that the fluorescence changes of QC are due to binding changes related to the pH differential between the inside and the outside of the activated membrane (4). Also other interpretations of the fluorescence changes have been suggested by Dell'Antone et al. (3).

The emphasis of this investigation has been to begin to clarify the role of QC in chloroplasts in the energized state by use of the technique of nanosecond fluorescence spectroscopy. In this method, the lifetime of the fluorescent probe is measured. In general, this gives more information than a measurement of the corresponding steady-state parameters such as fluorescent intensity and quantum yield. For instance, if a fluorescent probe binds at more than one site to a macromolecule, this can be detected by a lifetime measurement due to the appearance of one specific lifetime for each binding site. A quantum yield measurement would not be able to detect this complexity.

Materials and Methods

Class II chloroplasts from spinach (*Spinacea oleracea*) were prepared by the method of Vandermeulen and Govindjee (9) in 50 mM phosphate buffer (pH 7.8) containing 10 mM NaCl and 400 mM sucrose. Fluorescence decay measurements were carried out in a reaction mixture consisting of 3.3 mM phosphate buffer (pH 7.8), 3.3 mM $MgCl_2$, 16.7 mM KCl and 0.01 mM phenazinemethosulfate (PMS) as recommended by the same authors. Chlorophyll content, assayed according to Arnon (2), was adjusted to $10\mu g/ml$ in the experimental runs and QC³ was added to a final concentration of $10\mu M$.

The fluorescence experiments were carried out on a nanosecond flash apparatus with single-photon counting. The technique has been discussed elsewhere (1, 10). Figure 1 gives a schematic block diagram of the nanosecond fluorescence spectrometer available at Indiana State University. Light from a nanosecond pulse source (an air flash lamp, Ortec 9352) enters a filter or a monochromator (Schoeffel's miniature monochromator) and selected light excites a fluorochrome in the sample. The emitted fluorescent light is analyzed by a second filter or monochromator arrangement and is detected by a single photon counter (RCA 8850 photomultiplier). The time difference between the light source pulse and the arrival of a fluorescent light photon detected at the photomultiplier is converted to a pulse height in the time-to-pulse height converter (TAC). The pulses from the TAC-unit are then registered by a pulse-height multichannel analyzer. In this experiment the excitation light was selected by an absorption filter with maximum transmission at 350 nm. The fluorescent light from QC was observed through an absorption filter with maximum transmission at 510 nm. The sample was contained in a 2.0 ml quartz cuvette mounted for observation of front surface fluorescence and maintained at 0°C during measurement.

³ QC, quinaerine hydrochloride, is the Sigma Chemical Co. brand name of atebrine.

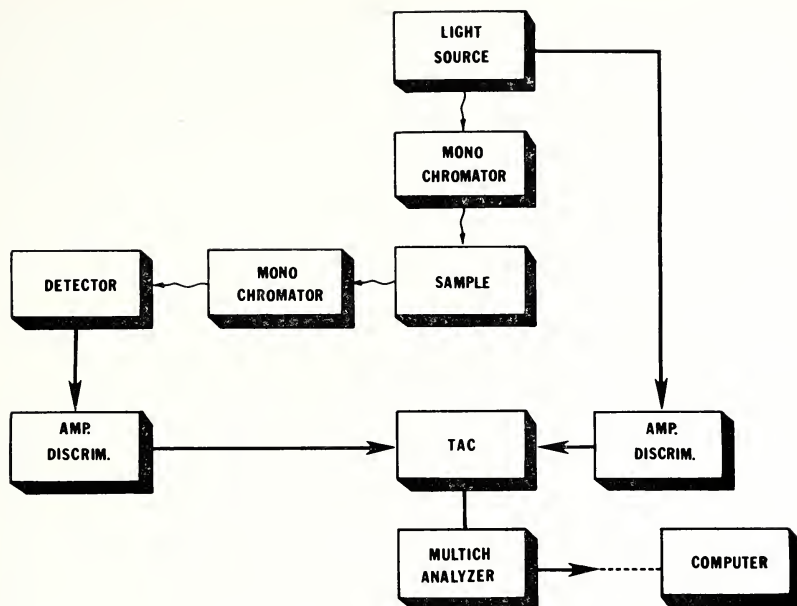


FIGURE 1. Block diagram of nanosecond fluorescence spectrometer.

Results

Figure 2 demonstrates representative decay curves obtained from QC in the complete reaction mixture containing the standardized concentration of chloroplasts.

The curve marked "light" was obtained from a sample which had been preilluminated with saturating white light (5 mw/cm^2) for 30 sec. at 0°C outside the fluorescence apparatus. The sample was then introduced into the fluorescence apparatus and decay curves registered for 10 sec. The time interval between the termination of light exposure and the start of fluorescence measurement was approximately 10 sec. This procedure was repeated four to six times with the same sample and results were summed. It is known (7) that the energized state of chloroplasts, under the conditions used in these experiments, has a relaxation time of about 50 sec., so that 10 sec. measurements avoided excessive error due to relaxation. At room temperature the relaxation time is considerably shorter (of the order of 10 s).

The curve marked "dark" represents traces which were identical when obtained from a sample prior to light exposure or returned to the dark for approximately 5 min. subsequent to light exposure.

The "light" decay curve consists of two components with lifetimes of $3.2 \pm 0.2 \text{ ns}$ and $9.2 \pm 0.5 \text{ ns}$, respectively. The "dark" decay curve also has two components with lifetimes of $4.2 \pm 0.3 \text{ ns}$ and $9.5 \pm 0.5 \text{ ns}$, respectively. The total intensity decrease in fluorescence from "dark" to "light" curves is 55%.

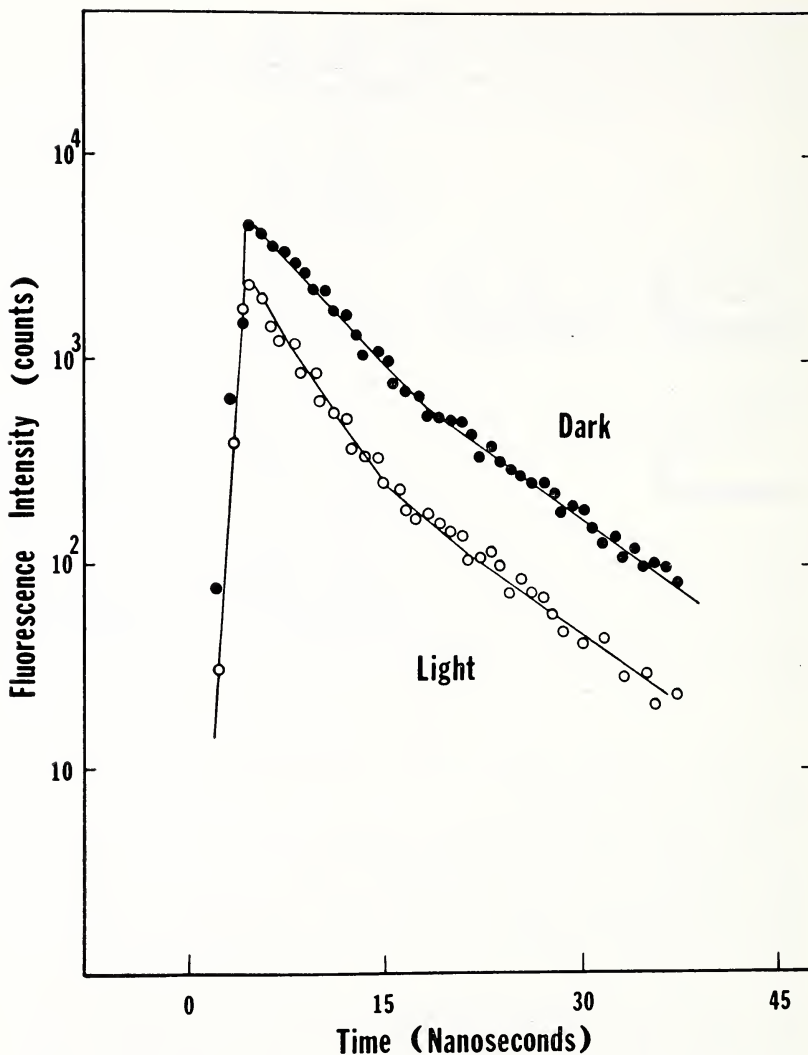


FIGURE 2. Fluorescence decay curves from quinacrine in chloroplasts. For details see text.

Since the pH values may be of importance in the systems considered here (4) fluorescence decay curves of QC solutions in various pH environments were also measured. Figure 3 shows the result for three different pH values measured at the same temperature used for the experiments presented in Fig. 2. As can be seen only small changes occur over a relatively broad range (pH 6.5-pH 7.5). A larger change is evident when pH is increased to 9.2.

Discussion

As shown in Figure 2, the change in fluorescence intensity of QC in chloroplasts upon irradiation with saturating light is due to a combination of two effects: (1) a decrease in fluorescence intensity of the longlived component without change in lifetime and (2) a change in lifetime of the shortlived component. We consider three possible expla-

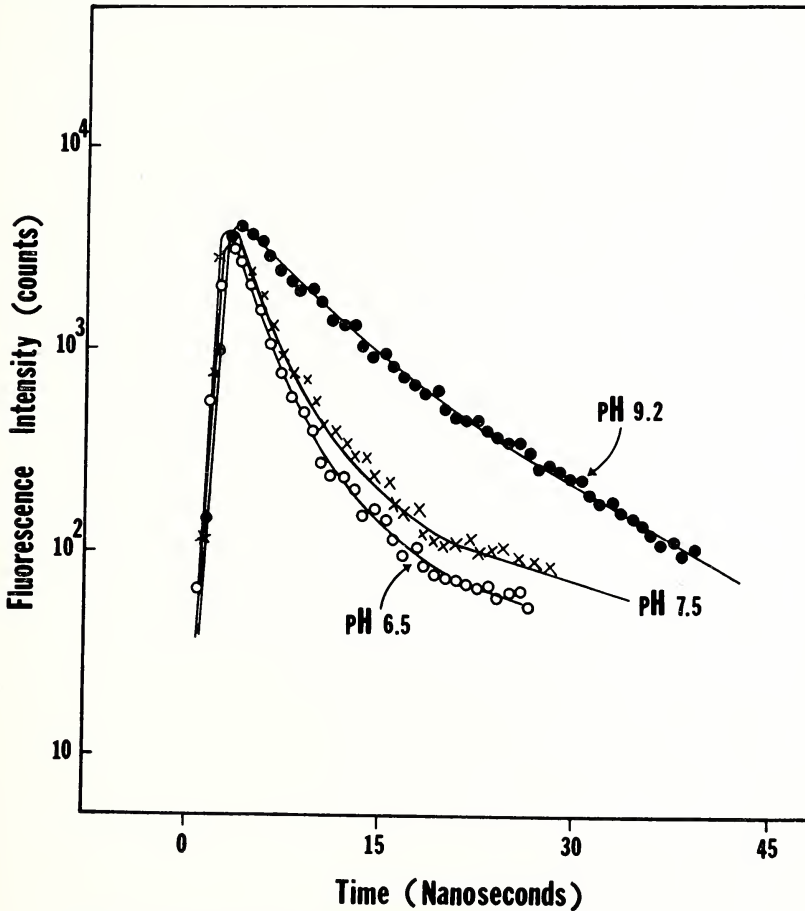


FIGURE 3. Fluorescence decay curves from quinacrine for three different pH values.

nations for the observed effect: actual binding of QC to the membranes with subsequent fluorescence decrease, changing environmental pH value, simple screening of the QC dye, or a combination of two or all of the above.

The observed effect as shown in Figure 2 can be explained by assuming that the QC binds at two different places on the membranes. One binding site gives rise to a slight change in the lifetime of the

shortlived component of the decay curve. The second binding site causes a complete quenching of the QC fluorescence. The difference in intensity between the "dark" curve and the "light" curve should then correspond approximately to unbound QC.

As illustrated in Figure 3, the pH value of the environment seen by the QC will influence the shape of the fluorescence decay curve. The maximum possible change in pH value of the membrane environment due to saturating light irradiation is estimated to be 0.3 units under conditions used here (Gross, unpublished results). No change of the fluorescence decay curve of QC can be detected with an environmental pH difference of this magnitude which is obviously too small to explain the measured effect of QC fluorescence decrease in the presence of the chloroplasts; a minor contribution from changing pH environments can not be totally excluded.

The third possible explanation would be that simple screening of the accumulated QC by chlorophyll or other membrane components caused the changes of the fluorescence decay curves. However, experiments with a wide variety of fluorochromes related to quinacrine with different positions of excitation and emission bands have demonstrated that a screening effect is very unlikely in the chloroplast system (7).

The conclusion is, therefore, that the most probable cause of the fluorescence lowering of QC in chloroplast systems exposed to saturating light is due to binding of the probe at two different binding sites, one of which is represented by the shortlived decay and is responsive to irradiation, the other, represented by the longlived decay which is not responsive to irradiation, although there was an intensity decrease upon illumination. A more detailed study is needed, however, in order to reach a firm conclusion and to ascertain the degree, however small, of the involvement of other effects than binding. In addition, further study of the role of QC in the energized state, using the nanosecond fluorescent technique, is clearly desirable in order to elucidate the mechanism of action of this fluorescent probe.

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PLANT TAXONOMY

Chairman: JOE F. HENNEN, Department of Botany and Plant Pathology
Purdue University, Lafayette, Indiana 47907

ORLAND J. BLANCHARD, Department of Biology
Earlham College, Richmond, Indiana 47374
was elected Chairman for 1976

ABSTRACTS

Plant Taxonomy at the Twelfth International Botanical Congress, Leningrad. THEODORE J. CROVELLO, Department of Biology, The University of Notre Dame, Notre Dame, Indiana 46556.—The International Botanical Congress was a great success in general, and for plant taxonomy in particular. Over 160 papers were presented in the section, Systematics and Evolutionary Botany, 72 being given in Russian. Of the remaining, 27 were by botanists from the United States, 25 from Western Europe, 22 from the Soviet Union and Eastern Europe, 5 from Canada, etc. In addition, symposia and contributed paper sessions were held on Cultivated Plants, Vascular Plants, Lower Plants, Floristics, and Phytogeography. A special symposium honored Vavilov. Many sessions were lively, and with or without interpreters, communication was effective much of the time. Our Soviet colleagues were most anxious to establish contact with western counterparts. Many Soviet workers reported on conventional approaches to systematics, but also Chemotaxonomic and computer approaches. Among the resolutions passed by the entire Congress was one calling for the creation of an international commission to advise and coordinate efforts in the use of data processing in systematics.

Preliminary Investigations of an Antheridogen System in the Fern Genus *Bommeria*. CHRISTOPHER H. HAUFLE and GERALD J. GASTONY, Department of Plant Sciences, Indiana University, Bloomington, Indiana 47401.—In gametophyte cultures of *Bommeria* species, both meristematic archegonial plants and ameristic antheridial plants occur. The presence of an antheridogen system regulating male sex expression was proposed to explain this observation. Three distinct types of antheridogen (male sex hormone) from ferns have been documented in the literature: antheridogen A from *Pteridium aquilinum*, antheridogen B from *Anemia phyllitidis*, and antheridogen C from *Ceratopteris thalictroides*. Evidence to date indicates that gametophytes of all investigated species of *Bommeria* respond positively to antheridogen A but do not form precocious antheridia in response to antheridogens B or C. In all species investigated, standard assays against the native *Bommeria* antheridogen indicate that it is the same as antheridogen A and that each species responds to the hormone of the other *Bommeria* species. The common occurrence of antheridogen production in the genus unifies this group of species and may isolate *Bommeria* from its close relatives.

Re-examination of a Numerical Taxonomic Study of *Solanum* Species and Hybrids. EDWARD E. SCHILLING, JR., Department of Plant Sciences,

Indiana University, Bloomington, Indiana 47401.—Data gathered by Heiser, Soria, and Burton (Amer. Natur. 99:471, 1965) on species and hybrids in the *Solanum nigrum* complex were re-examined using contemporary techniques of numerical analysis. Application of Gower's coefficient and WPGMA cluster analysis to the data matrix from which hybrid accessions had been removed resulted in OTU clusters which were in fair agreement with previously recognized species, indicating that the distortion of taxa in the original study was due to the influence of the hybrids. Principle components analysis of the complete data matrix revealed that two primary factors were involved in the relative placement of the OTU's: the intermediate character of hybrids relative to parents; and the ploidy level of hybrids and parents. Thus, several anomalous findings of the original study were explained. Hybrids of parents of different ploidy were placed closer to the parent of higher ploidy. The placement of some autopolyploids far from either parent was due to the effect of a ploidy level different from (and higher than) either parent. The positioning of a few hybrids closer to a non-parental species than to either parent was explained by the intermediate position of the non-parental species relative to the parents; in this way a clue to the possible lineage of species of likely hybrid origin might be gained. A final observation was the value of applying several types of numerical analysis to data gathered in studies of this type in extracting the maximum amount of useful information.

Computer Analysis of Selected Indiana Plant Distribution Patterns to Determine Phytogeographic Units. CLIFTON KELLER, Department of Biology, Andrews University, Berrien Springs, Michigan.—All of Deam's county distribution data for each of the approximately 2500 species of vascular plants recognized in 1940 as growing in Indiana have been computerized. Several selected subsets were chosen and analyzed. These ranged from considering species rare for Indiana (arbitrarily defined as those found in only six or less counties), to a "subset" that consisted of all of the species. From any one analysis, one can determine the number of species present in each county that have the chosen total county frequency. Thus, for example, the number of species that occur in St. Joseph County and in no more than five other counties can be determined. When this is done for every county, computer-generated maps can be produced that reflect statewide patterns. Certain results were anticipated, e.g., that the counties with the largest numbers of species rare for Indiana are in the northwest part of the State. Other patterns, after removing the possibility of being artifacts, were unexpected. The presence of three north-south ridges was not anticipated, and possible explanations are suggested. The general potential of such procedures was also presented.

Use of Computers to Determine the Endangered Status of Plant Species. THEODORE J. CROVELLO, Department of Biology, The University of Notre Dame, Notre Dame, Indiana 46556.—The rapidly increasing interest and concern for the fate of plant species possibly being driven to extinction by human activities has caught biologists unprepared. For several reasons, there simply are not enough trained systematists to give reliable

information on the endangered species status of the estimated 20,000 species of vascular plants indigenous to the United States. Endangered status can only be determined after a species' distribution has been determined not just in geographic space, but also over time. Herbaria represent the best reservoir of such information. But retrieving information from herbaria in an efficient way, to answer questions required for endangered species work is not easy, except with computers. Examples from an ongoing project in the mustard genera *Cardamine*, *Dentaria* and *Streptanthus* illustrate the potential. The current Mustard Data Bank consists of distribution, collection date and other information on 45,000 specimens from 75 museums. Summary tables of the number of specimens found in all combinations of county and decade are easy to prepare via computer. Computerization requires *financial* resources, but it may be the only means to help us to save our *natural* resources!

Additions to the Flora of Vigo County, Indiana. I.

MARION T. JACKSON, RONALD L. HELMS, and JOHN O. WHITAKER, JR.
Department of Life Sciences
Indiana State University, Terre Haute, Indiana 47809

Abstract

A total of 333 species of vascular plants are here reported as new records for Vigo County, Indiana, bringing the total number of species reported for the county to 830, representing 410 genera and 111 families.

Deam (2) apparently did not examine the collections in the Indiana State University (then Indiana State Teachers College) Herbarium prior to the publication of the *Flora of Indiana*. Consequently, a large number of relatively common species were not listed for the county on Deam's statewide plant distribution maps.

The purpose of this paper is to update the county flora to as complete a list of species as is possible at this time. Reported here are all vascular plant species contained in the ISU Herbarium that were collected within Vigo County, but which were not recorded for the county by Deam (2). Also included are records which have been published since those of Deam. In addition, extensive collecting during the past decade by Whitaker and Jackson resulted in several new county records. Helms' (10) intensive inventory of the Dobbs Park Nature Center provided a number of species new to the county.

No special effort was made to locate or to verify the continued presence of species previously reported for Vigo County. Many species, especially prairie species reported by Blatchley (1), likely no longer exist in the county.

Deam (2) listed a total of 489 vascular species for the county, representing 272 genera and 87 families. Records published subsequently to the *Flora of Indiana* included only an additional 8 species (3-8, 11). Including the species reported here, the vascular flora reported for the county totals 830 species, representing 410 genera and 111 families (Table 1).

Voucher specimens are located in the Indiana State University Herbarium. Nomenclature follows Little (12) for trees and Fernald (9) for non-arborescent species.

Acknowledgment

We acknowledge the assistance of Dr. John Ebinger, Eastern Illinois University, in verifying several grass and sedge species.

TABLE 1. *Floral additions for Vigo County, Indiana.*

ACERACEAE	CELASTRACEAE
<i>Acer nigrum</i> Michx. f.	¹ <i>Euonymus alatus</i> (Thunb.) Sieb.
<i>Acer rubrum</i> L.	<i>Euonymus obovatus</i> Nutt.
<i>Acer saccharinum</i> L.	CERATOPHYLLACEAE
AIZOACEAE	<i>Ceratophyllum demersum</i> L.
<i>Mollugo verticillata</i> L.	CHENOPODIACEAE
ALISMATACEAE	<i>Chenopodium album</i> L.
<i>Sagittaria latifolia</i> Willd.	<i>Chenopodium capitatum</i> (L.) Aschers.
AMARANTHACEAE	COMMELINACEAE
<i>Amaranthus hybridus</i> L.	<i>Commelina communis</i> L.
<i>Amaranthus retroflexus</i> L.	<i>Commelina virginica</i> L.
<i>Froelichia gracilis</i> (Hook.) Moq.	<i>Tradescantia virginiana</i> L.
ANNONACEAE	COMPOSITAE
<i>Asimina triloba</i> (L.) Dunal.	<i>Achillea Millefolium</i> L.
APOCYNACEAE	<i>Ambrosia artemisiifolia</i> L.
<i>Apocynum cannabinum</i> L.	<i>Ambrosia psilostachya</i> D.C.
¹ <i>Vinca minor</i> L.	<i>Ambrosia trifida</i> L.
ARACEAE	<i>Antennaria neglecta</i> Greene.
<i>Acorus Calamus</i> L.	<i>Antennaria plantaginifolia</i> (L.) Hook
<i>Arisaema triphyllum</i> (L.) Schott.	<i>Anthemis Cotula</i> L.
ARISTOLOCHIACEAE	<i>Arctium minus</i> (Hill) Bernh.
<i>Asarum canadense</i> L.	<i>Aster cordifolius</i> L.
ASCLEPIADACEAE	<i>Bidens bipinnata</i> L.
<i>Asclepias syriaca</i> L.	<i>Bidens comosa</i> (Gray) Wieg.
<i>Asclepias verticillata</i> L.	<i>Bidens coronata</i> (L.) Britt.
BALSAMINACEAE	<i>Cacalia atriplicifolia</i> L.
<i>Impatiens biflora</i> Walt.	<i>Chrysanthemum Leucanthemum</i> L.
<i>Impatiens pallida</i> Nutt.	<i>Cirsium arvense</i> (L.) Scop.
BERBERIDACEAE	<i>Conyza canadensis</i> (L.) Cronq.
<i>Berberis vulgaris</i> L.	<i>Eclipta alba</i> (L.) Hassk.
<i>Jeffersonia diphylla</i> (L.) Pers.	<i>Erigeron philadelphicus</i> L.
<i>Podophyllum peltatum</i> L.	<i>Erigeron strigosus</i> Muhl.
BETULACEAE	<i>Eupatorium perfoliatum</i> L.
<i>Betula nigra</i> L.	<i>Galinsoga ciliata</i> (Raf.) Blake
¹ <i>Betula papyrifera</i> Marsh.	<i>Helenium flexuosum</i> Raf.
<i>Carpinus caroliniana</i> Walt.	<i>Helianthus decapetalus</i> L.
BIGNONIACEAE	<i>Heliopsis helianthoides</i> (L.) Sweet
<i>Campsis radicans</i> L. Seem.	<i>Hieracium Gronovii</i> L.
<i>Catalpa speciosa</i> Warder.	<i>Lactuca biennis</i> (Moench) Fern.
BORAGINACEAE	<i>Lactuca canadensis</i> L.
<i>Myosotis verna</i> Nutt.	<i>Lactuca floridana</i> (L.) Gaertn.
CAPRIFOLIACEAE	<i>Matricaria matricarioides</i> (Less.) Porter.
¹ <i>Lonicera japonica</i> Thunb.	<i>Prenanthes altissima</i> L.
<i>Symphoricarpos orbiculatus</i> Moench.	<i>Rudbeckia triloba</i> L.
<i>Viburnum Lentago</i> L.	<i>Senecio aureus</i> L.
<i>Viburnum prunifolium</i> L.	<i>Senecio vulgaris</i> L.
<i>Viburnum opulus</i> L.	<i>Silphium integrifolium</i> Michx.
<i>Viburnum Rafinesquianum</i> Schultes.	<i>Sonchus oleraceus</i> L.
CARYOPHYLLACEAE	<i>Taraxacum officinale</i> Weber.
<i>Agrostemma Githago</i> L.	<i>Verbesina alternifolia</i> (L.) Britt.
<i>Cerastium viscosum</i> L.	CONVOLVULACEAE
<i>Cerastium vulgatum</i> L.	<i>Convolvulus arvensis</i> L.
<i>Lychnis alba</i> Mill.	<i>Ipomoea pandurata</i> (L.) G. F. W. Mey.
<i>Silene antirrhina</i> L.	CORNACEAE
<i>Silene Cucubalus</i> Wibel.	<i>Cornus racemosa</i> Lam.
<i>Silene virginica</i> L.	<i>Nyssa sylvatica</i> Marsh.
<i>Stellaria media</i> (L.) Cyrillo.	CRASSULACEAE
	<i>Sedum ternatum</i> Michx.

¹Cultivars reproducing naturally.

TABLE 1. (cont.)

CRUCIFERAE

- Barbarea vulgaris* R.Br.
Brassica campestris L.
Brassica juncea (L.) Coss.
Brassica nigra L. (Roch.)
Capsella Bursa-pastoris (L.) Medic.
Cardamine bulbosa (Schreb.) BSP.
Cardamine Douglassii (Torr.) Britt.
Dentaria laciniata Muhl.
Draba verna L.
Iodanthus pinnatifidus (Michx.) Steud.
Lepidium campestre (L.) R. Br.
Lepidium virginicum L.
Thlaspi arvense L.

CUPRESSACEAE

- Juniperus virginiana* L.

CYPERACEAE

- Bulbostylis capillaris* (L.) C. B. Clarke
Carex Grayii Carey
Carex laxiflora Lam.
Scirpus americanus Pers.
Scirpus cyperinus (L.) Kunth.
Scirpus lineatus Michx.

DIPSACACEAE

- Dipsacus sylvestris* Huds.

DIOSCOREACEAE

- Dioscorea villosa* L.

EBENACEAE

- Diospyros virginiana* L.

EQUISETACEAE

- Equisetum arvense* L.
Equisetum hyemale L.

EUPHORBIACEAE

- Croton glandulosus* L.
Euphorbia commutata Engelm.
Euphorbia marginata Pursh.

FAGACEAE

- Fagus grandifolia* Ehrh.
Quercus bicolor Willd.
Quercus muehlenbergii Engelm.
Quercus palustris Muenchh.
Quercus rubra L.
Quercus velutina Lam.

GENTIANACEAE

- Obolaria virginica* L.
Sabatia angularis (L.) Pursh.

GRAMINEAE

- Agropyron repens* (L.) Beauv.
Agrostis stolonifera L.
Andropogon virginicus L.
Bromus japonicus Thunb.
Bromus tectorum L.
Cenchrus longispinus (Hack.) Fern.
Dactylis glomerata L.
Danthonia spicata (L.) Beauv.
Elymus villosus Muhl.
Festuca clatior L.
Festuca villosus Muhl.

- Hordeum jubatum* L.
Apios americana Medic.
Panicum agrostoides Spreng.
Panicum depauperatum Muhl.
Panicum huachucae Ashe.
Panicum lanuginosum Ell.
Panicum latifolium L.
Panicum spretum Schultes.
¹*Phleum pratense* L.
Poa compressa L.
Poa pratensis L.
Setaria Faberii Herrm.
Setaria viridis (L.) Beauv.
Sorghum halpense (L.) Pers.
Sorghum halepense (L.) Pers.
Uniola latifolia Michx.

HAMAMELIDACEAE

- Liquidambar styraciflua* L.

HIPPOCASTANACEAE

- Aesculus glabra* Willd.

HYDROCHARITACEAE

- Vallisneria americana* Michx.

HYDROPHYLLACEAE

- Hydrophyllum macrophyllum* Nutt.

IRIDACEAE

- Iris Shrevei* Small.
Iris virginica L.
Sisyrinchium graminoides Bickn.

JUGLANDACEAE

- Carya laciniata* (Michx. f.) Loud.
Carya ovalis (Wangenh.) Sarg.
Carya ovata (Mill.) K. Koch.
Carya tomentosa Nutt.
Juglans cinerea L.

JUNCACEAE

- Juncus bufonius* L.
Juncus Dudleyi Wieg.
Juncus effusus L.
Juncus interior Wieg.
Juncus tenuis Willd.
Juncus Torreyi Coville.

LABIATAE

- Agastache scrophulariaefolia* (Willd.) Ktze.
Collinsonia canadensis L.
Glechoma hederacea L.
Lamium amplexicaule L.
Lamium purpureum L.
Leonurus Cardiaca L.
Mentha spicata L.
Nepeta Cataria L.
Physostegia virginiana L. (Benth.)
Scutellaria lateriflora L.
Scutellaria nervosa Pursh.
Stachys aspera
Trichostema dichotomum L.

LAURACEAE

- Lindera Benzoin* (L.) Blume

¹Cultivars reproducing naturally.

TABLE 1. (cont.)

LEGUMINOSAE

- Amphicarpa bracteata* (L.) Fern.
Apios americana Medic.
Cercis canadensis L.
Desmodium glabellum (Michx.) D.C.
Gleditsia triacanthos L.
Gymnocladus dioica (L.) K. Koch.
¹*Lepedeza cuneata* (Dumont) G. Don.
Lepedeza virginica (L.) Britt.
Medicago lupulina L.
¹*Melilotus alba* Desr.
¹*Melilotus officinalis* (L.) Lam.
Robinia pseudoacacia L.
Strophostyles leiosperma (T.&G.) Piper
Trifolium agrarium L.
¹*Trifolium hybridum* L.
¹*Trifolium pratense* L.
Trifolium procumbens L.
Trifolium repens L.

LEMNACEAE

- Lemna minor* L.
Spirodela polyrrhiza (L.) Schleid.

LILIACEAE

- Allium canadense* L.
Allium cernuum Roth.
Allium vineale L.
Asparagus officinalis L.
Erythronium americanum Ker.
Hemerocallis fulva L.
Ornithogalum umbellatum L.
Polygonatum biflorum (Walt.) Ell.
Smilacina racemosa (L.) Desf.
Smilax herbacea L.
Smilax rotundifolia L.
Trillium Gleasoni Fern.
Trillium recurvatum Beck.
Trillium sessile L.
¹*Yucca filamentosa* L.

LYCOPODIACEAE

- Lycopodium complanatum* L. Var.
flabelliforme Fern.

MALVACEAE

- Abutilon Theophrasti* Medic.
Malva neglecta Wallr.
Sida spinosa L.

MORACEAE

- Humulus Lupulus* L.
Maclura pomifera (Raf.) Schneid.

MORACEAE

- Morus alba* L.
Morus rubra L.

NYMPHAEACEAE

- Nuphar advena* (Ait.) Ait.f.

OLEACEAE

- Fraxinus americana* L.
Fraxinus profunda (Bush) Bush
Fraxinus nigra Marsh.

- Fraxinus quadrangulata* Michx.
Ligustrum vulgare L.

ONAGRACEAE

- Circaea quadrisulcata* (Maxim.) Franch.
 & Sav.
Gaura filipes Spach.
Jussiaea repens L.
Ludwigia palustris (L.) Ell.
Oenothera biennis L.
Oenothera tetragona Roth.

OPHIOGLOSSACEAE

- Botrychium dissectum* Spreng.

ORCHIDACEAE

- Orchis spectabilis* L.
Spiranthes gracilis (Bigel.) Beck.

OSMUNDACEAE

- Osmunda Claytoniana* L.

OXALIDACEAE

- Oxalis stricta* L.
Oxalis violacea L.

PAPAVERACEAE

- Sanguinaria canadensis* L.

PHYTOLACCACEAE

- Phytolacca americana* L.

PINACEAE

- ¹*Pinus banksiana* Lamb.
¹*Pinus resinosa* Ait.
¹*Pinus strobus* L.
¹*Pinus sylvestris* L.

PLANTAGINACEAE

- Plantago lanceolata* L.
Plantago major L.

PLATANACEAE

- Platanus occidentalis* L.

POLEMONIACEAE

- Phlox maculata* L.
Polemonium reptans L.

POLYGONACEAE

- Fagopyrum esculentum* Moench.
Polygonum aviculare L.
Polygonum Convolvulus L.
Rumex Acetosella L.
Rumex crispus L.
Rumex mexicanus Meissn.
Rumex obtusifolius L.
Rumex venosus Pursh.

POLYPODIACEAE

- Cystopteris bulbifera* (L.) Bernh.
Dryopteris marginalis (L.) Gray
Dryopteris spinulosa (O. F. Muell.) Watt.
Dryopteris noveboracensis (L.) A. Gray

PORTULACACEAE

- Claytonia virginica* L.

PRIMULACEAE

- Lysimachia Nummularia* L.

RANUNCULACEAE

- Anemonella thalictroides* (L.) Spach.

¹Cultivars reproducing naturally.

TABLE 1. (cont.)

RANUNCULACEAE (Cont.)		<i>Verbascum Blattaria</i> L.
<i>Clematis virginiana</i> L.		<i>Verbascum Thapsus</i> L.
<i>Hepatica acutiloba</i> D.C.	SIMAROUBACEAE	
<i>Ranunculus abortivus</i> L.	<i>Ailanthus altissima</i> (Mill.) Swingle.	
<i>Ranunculus acris</i> L.	SOLANACEAE	
<i>Ranunculus hispidus</i> Michx.	<i>Datura Stramonium</i> L.	
<i>Ranunculus septentrionalis</i> Poir.	<i>Physalis pubescens</i> L.	
	<i>Solanum Dulcamara</i> L.	
ROSACEAE	<i>Solanum nigrum</i> L.	
<i>Agrimonia gryposepala</i> Wallr.	STAPHYLEACEAE	
<i>Amelanchier laevis</i> Wieg.	<i>Staphylea trifolia</i> L.	
<i>Crataegus crus-galli</i> L.	TYPHACEAE	
<i>Fragaria virginiana</i> Duchesne.	<i>Typha latifolia</i> L.	
<i>Geum canadense</i> Jacq.	ULMACEAE	
<i>Geum vernum</i> (Raf.) T. & G.	<i>Celtis occidentalis</i> L.	
<i>Physocarpus opulifolius</i> (L.) Maxim.	<i>Ulmus americana</i> L.	
<i>Potentilla recta</i> L.	<i>Ulmus thomasi</i> Sarg.	
<i>Potentilla simplex</i> Michx.	UMBELLIFERAE	
<i>Prunus americana</i> Marsh.	<i>Conium maculatum</i> L.	
¹ <i>Prunus Persica</i> L. Patsch.	<i>Daucus Carota</i> L.	
<i>Prunus serotina</i> Ehrh.	<i>Osmorhiza Claytoni</i> (Michx.) C. B. Clarke	
<i>Pyrus coronaria</i> L.	<i>Pastinaca sativa</i> L.	
<i>Rosa multiflora</i> Thunb.	<i>Sanicula gregaria</i> Bickn.	
<i>Rubus allegheniensis</i> Porter.	<i>Sanicula trifoliata</i> Bickn.	
<i>Rubus flagellaris</i> Willd.	<i>Sium suave</i> Walt.	
<i>Rubus occidentalis</i> L.	URTICACEAE	
RUBIACEAE	<i>Boehmeria cylindrica</i> (L.) Sw.	
<i>Diodia teres</i> Walt.	<i>Laportea canadensis</i> (L.) Wedd.	
<i>Galium Aparine</i> L.	<i>Parietaria pensylvanica</i> Muhl.	
RUTACEAE	VERBENACEAE	
<i>Ptelea trifoliata</i> L.	<i>Verbena urticifolia</i> L.	
SALICACEAE	VIOLACEAE	
<i>Populus deltoides</i> Marsh.	<i>Viola eriocarpa</i> Schwein	
<i>Populus grandidentata</i> Michx.	<i>Viola papilionacea</i> Pursh.	
<i>Salix discolor</i> Muhl.	<i>Viola pubescens</i> Ait.	
<i>Salix nigra</i> Marsh.	<i>Viola sororia</i> Willd.	
SCROPHULARIACEAE	<i>Viola striata</i> Ait.	
<i>Linaria vulgaris</i> Hill.	VITACEAE	
<i>Scrophularia marilandica</i> L.	<i>Vitis aestivalis</i> Michx.	

¹Cultivars reproducing naturally.

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SCIENCE EDUCATION

Chairman: LEON BERNHARDT, Department of Biology
Ball State University, Muncie, Indiana 47306

HAROLD H. JAUS, Department of Education
Purdue University, Lafayette, Indiana 47907
was elected Chairman for 1976

ABSTRACTS

The Value of Literature for Teaching Science to Science Majors. SANDRA WINICUR, Department of Biological Sciences, Indiana University at South Bend, South Bend, Indiana 46615.—The use of literature is encouraged to aid science majors in understanding the values of science and scientists. Because of the difficulty of the discipline, science students tend to lack first-hand experience with the human and the creative side of science. This need can be approached by a seminar course using well-written fictional and semi-fictional works by authors who demonstrate good insight into the scientific process.

The use of literature in this interdisciplinary manner to develop humanistic attitudes towards science on the part of the science majors, and the use of strong science background in discussing the basic ideas of these literary works, will hopefully tend to counteract the extreme specialization that one sees all too often in college students.

Changing Elementary Teachers' Attitudes Toward Science Process Skill-Oriented Instruction. HAROLD H. JAUS, Assistant Professor of Science Education, Purdue University, West Lafayette, Indiana 47907.—The purpose of this study was to determine if inservice elementary teachers' science teaching attitudes could be altered toward acceptance of a science process skill-oriented mode. Thirty-three teachers enrolled in a four-week summer NSF Implementation Program were involved in the study. This summer program consisted of training the teachers in the science process skills. Upon completion of this training, the teachers taught ESS and S-APA science lessons to groups of 8-10 children for a period of two weeks. At the onset and completion of the NSF Program the teachers were administered the Jaus Science Teaching Attitude Scale. This Likert-type instrument was designed to measure teachers' attitudes toward teaching science as a body of knowledge or as a process. Pre- and post-test scores from this instrument were analyzed by t-tests. Significant results indicated that elementary teachers' science teaching attitudes can be changed toward a more process skill-oriented mode.

Soil Section of an Adult Class in Agriculture. JAMES MITCHELL SMITH, Instructor, Veteran Agricultural Class, New Castle Area Vocational School, New Castle, Indiana 47362.—Soils information for an upland farm in Henry County, Indiana was presented using, in this order:

- 1) Dunreith Quadrangle 7.5' sheet.
- 2) Air photo N.C. 1-KK 1969—66 and a mate for a stereo pair.

- 3) Completed soils map of the farm. Explanation of Great Soil Group, catena, soils type, soils texture, slope and erosion. (Mapping Unit).
- 4) A similar upland area in Madison County, Indiana was studied on a finished Soil Survey Report. No such report is now available in Henry County.
- 5) A visit to the farm over a period of several hours with the above material and a soils auger. Detailed study of Crosby, Brookston and Miami soils.

The farm was that of Mr. Russell Bridges, a man greatly interested in education, and is near the junction of highways 3 and 70 and easily reached from any point in the state.

This method of presenting soils information can be used in many parts of the United States.

A Biomes Survey Trip of the South and Southwestern U.S. JACKSON L. MARR, MARLENE V. SHAW, and JOHNNY W. REISING, Life Science Department, Indiana State University Evansville, Evansville, Indiana 47712. —An inexpensive 5800-mile, 23-day field trip was taken by 22 people through the southeast pine timber, Texas gulf coast, southwest desert, Rocky Mountain coniferous forest, tundra, and short and long grassland prairies. The logistics and organization in addition to the trip will be discussed.

Viscosity Determination. ROLLA M. DYER and JACKSON L. MARR, Division of Science and Mathematics, Indiana State University Evansville, Evansville, Indiana 47712. —An extension of the settling sphere technique for the determination of viscosity of liquids to accommodate a wider range of substances, making possible the use of water as a standard has been developed. By using 5 mesh or smaller aluminum shot it has been possible to extend the elapsed time of the sphere settling.

Science Education and the Right Side of the Brain. H. MARVIN BRATT, Assistant Professor, Early and Middle Childhood Education, The Ohio State University, Marion, Ohio. —A series of pilot studies were conducted to determine whether left-handed children were more able to perform on tasks of visuo-spatial activity than right-handed children. Tangrams, a set of puzzles developed by the Webster Division, McGraw-Hill Publishing Co. were used as visuo-spatial tasks. Left-handed children were able to do a set of twenty-seven (27) puzzles in less time than right-handed children. University students were able to do the same tasks in less time. Young children (left handed) seemed to have more difficulty drawing certain objects with their right hands.

There may be differences in ability to solve tasks as well as a developmental scheme for these abilities. Further research along these lines is forthcoming.

The Geosciences Today—An Introductory Seminar. GERALD H. KROCK-OVER, Associate Professor of Education and Geosciences, Purdue University, West Lafayette, Indiana 47907. —The Purdue University Department of Geosciences has initiated an undergraduate seminar for freshmen expressing an interest in the geosciences. The seminar is de-

signed to acquaint entering university students with the opportunities available in the geosciences in general and with specific departmental programs. Thirteen sessions were conducted during the fall semester, 1974, and an evaluation instrument was administered to the students enrolled. Seminars such as these can serve as a valuable adjunct to the undergraduate science program and can provide many benefits to both the student and science faculty.

Individually Paced Curricular Materials for Developing Science Process Skills in Preservice Elementary School Teachers

JON R. HENDRIX, Ed.D.
Ball State University, 1974

The primary goal of this research project was to produce and test individually paced curricular materials designed to develop basic science process skill competency in preservice elementary school teachers. The four basic science process skills of observing, measuring, classifying, and predicting were identified for the study. Evidence accumulated through three approaches substantiated preservice teachers' needs for further development of these four process skills. The need for science process skill study was based upon recommendations of The American Association for the Advancement of Science, upon the results of a science process measure for teachers administered to a population of preservice elementary school teachers, and upon nine years of personal observation by the researcher in his capacity as a public school science supervisor.

In developing the project a sequence of performance steps was established, taking into consideration current trends in elementary science education, individualization of instruction, and educational accountability. This systems model embodied the development of specifically stated performance objectives for each process skill identified for the study. Eight prototype process skill tests were constructed consisting of a pre/post-test for each of the four process skill areas. The tests were validated by expert opinion. Four individualized learning guides, one for each process skill area, were created to be used with preservice elementary school teachers in elementary science methods courses. An instructors' guide was developed to accompany the student materials. The format for each student guide included a rationale, performance objectives, and a sequence of activities designed to facilitate the attainment of the objectives. A different content carrier was selected to be used in developing each of the four process skill areas. Selected content from the Elementary Science Study program was used in the development of the observation process skill. Selected content from the Science-A Process Approach program was used in the development of the measuring process skill. Selected content from the Science Curriculum Improvement Study program was used in the development of the classifying process skill. And materials of the researcher's design, problem-solving activities related to the concept of change, were used in the development of the predicting process skill. The prototype materials were tested during the Spring and Summer Quarters of 1973 and revisions were made on the basis of this testing. The revised materials were pilot tested during the Fall Quarter of the 1973-74 school year with six sections of Ball State University elementary science methods students. As a result of the pilot testing a new multiple choice process pre/post-test was created and revisions in the teachers' guide were made. Final testing of the curricular materials occurred during the Winter Quarter

of the 1973-74 school year with four sections of elementary methods students.

Statistical treatment of the data collected during the final testing of the materials included analysis of individual pre/post-test scores, pre/post-test variance, per cent of growth applied to an established competency criterion and the application of a one-tailed t test testing the null hypothesis that the mean of the difference between the paired measures (pre/post-test scores) is zero.

The feasibility of creating individually paced, science process skill curricular materials using a systems approach and merging selected content goals of elementary science methods with science process skill acquisition goals was established in this study. The population of pre-service elementary school teachers who used the curricular materials met the established competency criterion for all four process skills. Data from this study provide a model for further development of other science process skill building curricular materials for preservice elementary school teachers.

SOIL AND ATMOSPHERIC SCIENCES

Chairman: FRANK W. SANDERS, Soil Conservation Service
5610 Crawfordsville Road, Indianapolis, Indiana 46224

HARRY M. GALLOWAY, Department of Agronomy
Purdue University, Lafayette, Indiana 47907
was elected Chairman for 1976

ABSTRACTS

Procedures and Techniques Developed at the Soil Characterization Laboratory at Purdue University. GARY C. STEINHARDT and DONALD P. FRANZMEIER, Agronomy Department, Purdue University, West Lafayette, Indiana 47907.—A Soil Characterization Laboratory has been established in the Agronomy Department of Purdue University as part of the accelerated soil survey program for Indiana. The purpose of this laboratory is to analyze soils submitted by field soil scientists to assist in the classification and mapping of the soils. The analyses that are required on each sample include: particle size distribution, pH, cation exchange capacity, exchangeable bases, extractable acidity, percent base saturation, and organic carbon. Each of the analyses performed by the laboratory follows a standard method but in serving the needs of a large field staff rapid techniques to analyze large numbers of samples were developed. These techniques allowed the laboratory to reach production goals for one trained analyst of 30 particle size analyses per day or 32 extractable acidity, 32 exchangeable bases per day, and 30 organic carbon analyses per day. An important element in the laboratory operation has been the use of the MIRACLE computer project to calculate data. It does in a matter of a few minutes what would take hours using conventional calculators.

Time-Lapse Techniques for Everyone. C. R. CHURCH, Geosciences Department, Purdue University, West Lafayette, Indiana 47906.—Meteorological and agricultural events have a common feature in that they occur on a time scale which is long compared with that of human activity. Time-lapse photography is a valuable aid in gaining a clearer perception of the physical development or behavior of such phenomena. Sophisticated time-lapse systems are available at sometimes prohibitive cost. This paper, on the other hand, outlines how time-lapse sequences can be made reliably through simple modifications to different inexpensive movie cameras. Various time-lapse techniques are reviewed, together with criteria for determining which to use. General details of how each may be implemented are presented. Procedures for selection of lenses, uses of filters, and determination of exposure settings are provided. Time-lapse film sequences of convective clouds are shown to demonstrate the quality of the end product.

The Classification of the Soil Formed from the Kope Formation of Ordovician Age Soft Calcareous Shales and Limestone in Southeastern Indiana. L. D. NORTON and A. L. ZACHARY, Purdue University, Lafayette,

Indiana 47907.—This study presents field and laboratory data to characterize the soils formed from the Kope formation of Ordovician Age soft calcareous shales and limestone in Dearborn and Ohio counties. The problem was to determine if a new soil series should be established for these soils. There were two areas of concern about the classification: first, the amount of coarse fragments—whether these soils contained enough coarse fragments to be placed into a skeletal family, and second the kind of clay minerals in the clay fraction. It was determined that these soils contained less than 35% by volume of coarse fragments in the control section so they are not in a skeletal family. There was no one dominant clay mineral present in the clay fraction. These soils would therefore classify as members of the fine, mixed, mesic family of Typic Hapludalfs in Soil Taxonomy and are being mapped as the Pate Series.

Comparison of Soils and Residues with Soybeans in Pots Using Subirrigation. RUSSELL K. STIVERS, Department of Agronomy, Purdue University, West Lafayette, Indiana 47907.—Sampled portions of the plow horizon of eight high yielding soils, each with and without incorporated ground corn (*Zea mays* L.) stover residues were compared in growing soybeans (*Glycine max* L.) outside in clay pots during June, July, and August 1975. Six randomized replications were used. Water was supplied by subirrigation when necessary. Above-ground portions of the soybean plants were measured for height, harvested, and dried when the first pods began to form. Plants grown on Brookston, Ragsdale, and Iva soils had more dry matter than those grown on Crosby, Reesville, and Zipp soils. The same trend was evident in the height measurements. Incorporated corn stover residues produced shorter plants with lower dry matter yields than did the no residue treatment. Leaf composition data and root studies suggested that high soil moisture accompanying subirrigation may have limited root nodule effectiveness in supplying nitrogen.

Soils and Their Interpretations. H. RAYMOND SINCLAIR, United States Department of Agriculture, Soil Conservation Service, Indianapolis, Indiana 46224.—Soils as they are to the users of soil surveys consist of taxonomic units and mapping units. Taxonomic units are for the sole purpose of being useful. Mapping units are based upon the principle that certain soils are more similar than others and therefore respond the same to similar use and management. Interpretations of soils reflect the knowledge acquired through observations, studies, and research.

Denitrification in Indiana Lake, Pond, and Reservoir Sediments. RICHARD E. TERRY and DARRELL W. NELSON.—Denitrification is a microbial transformation of nitrogen which converts nitrate to nitrogen gas. In view of the problems associated with the increased fertility and subsequent eutrophication of surface water it is important that more be known about the capacities of lake, pond, and reservoir sediments for denitrification. The denitrification rates of sediments from 12 Indiana lakes, ponds, and reservoirs were determined in the laboratory. Denitrification rates of 51 to 171 $\mu\text{g NO}_3^-$ —N per g of sediment per day were

observed in 5 lake sediments, whereas, denitrification rates of from 28 to 71 $\mu\text{g NO}_3^-$ -N per g of sediment per day were observed in 7 pond and reservoir sediments.

The chemical properties of the 12 sediments were determined and compared with the denitrification rates of the sediments. Simple correlation techniques revealed that only the calcium carbonate content of sediments was related to denitrification rate. The 12 sediments exhibited large capacities for nitrate removal by denitrification. The findings show that denitrification in sediments may be an important factor in the nitrogen budget of lakes, ponds, and reservoirs. The levels of nitrate in surface waters may be limited naturally by denitrification in the sediments.

Computation of Potential Evaporation on an Hourly Basis Using Online Computer Acquisition and Processing. W. A. BRUNS and A. R. PEREIRA, Department of Agronomy, Purdue University, West Lafayette, Indiana 47907.—A computer based data acquisition and processing system is used to record and store meteorological data through the MICROS/MIRACLE system at Purdue University. The data are available to the user in realtime, and computer processing of these data provides for the immediate application of the meteorological data. An example of the application of the system is demonstrated by the computation of potential evaporation on an hourly basis using the Van Bavel combination approach (1966). Comparison of the calculated values with other methods of determining potential evaporation are given.

The Effect of Soil Moisture on Pan Evaporation. ROBERT F. DALE and KENNETH L. SCHEERINGA, Agronomy Department, Purdue University, West Lafayette, Indiana 47907.—Crop production in the Corn Belt is largely controlled by the soil moisture supply and attendant atmospheric evaporative demand. The most widely accepted method of estimating the potential evaporation (E_0) is the Penman equation, which includes both the net radiation and advected energy components. Measurements from evaporimeters are also widely used. Because of "microadvective" conditions, measurements of evaporation from the Class A pan usually are higher than the Penman estimates of E_0 , requiring pan calibration for the local environment. The microadvective effect, sometimes called the "oasis" or "clothesline" effect, was evaluated empirically as a function of the plant available soil moisture (PAV) in the top 15 cm. When soil moisture near the weather station was at full water holding capacity (100% PAV), E_0 was very close to pan evaporation (E_p). The E_p/E_0 ratio increased with decreasing soil moisture, being about 1.2 with 60% PAV, and 1.4 with 20% PAV.

Radar Indications of Weather Modification. LAWRENCE A. SCHAAL, Agronomy Department, Purdue University, West Lafayette, Indiana 47907.—Because known ground based seeding of clouds in northern Indiana with silver iodide was taking place in the summer of 1974, it was decided to review the pictures of the radar scope taken at Marseilles, southeast of Chicago. The National Weather Service radar has a range of 250 miles. The film reviewed consisted of pictures taken about every 6 minutes from

mid-July to mid-August whenever activity was occurring. The film can be shown in time-lapse mode or viewed one picture or frame at a time.

The simple review technic was to use an overlay showing the location of the Indiana seeding stations as indicated by the commercial seeder and observe if any rain echoes occurred exclusively at or downstream from the station. Widespread rain cloud masses were exempt from consideration. The author selected 5 cases where rain appeared to be local to the seeding point. After their selection it was learned that in two cases seeding was in progress. It is obvious that results were inconclusive as were those in Michigan by Dale Linvill and Joe Waters. They counted the number of storm cells passing through two target areas and corresponding selected control areas in central Lower Michigan using Detroit radar pictures. In one pair of areas the target area had a higher count than the control area. It was the opposite in the second pair of areas with the control area having the higher count.

It is apparent that the seeding activity was not of sufficient consequence to show up in an obvious way on the radar scopes at Marseilles or at Detroit.

Soil Information for Land Use Decisions: A Scientific Approach

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Abstract

Demand on our land resources have been increasing. Land use is a complex problem. We must make every effort to insure that the varied uses of the land are harmoniously related to the soil productivity with sound economic judgments while not being detrimental to the environment. Soil surveys provide physical information of unique value to help decision makers but are complex to use and understand. Detailed large-scale maps serve users well in planning for detailed site selection. Detailed soil maps can be made more useful by analyzing soils for combinations of factors which contribute to success of various land uses and which make economic assessment possible. Then various courses of action can be compared for efficient suitability for community planning. Computer methods of handling the soil property information make soil maps usage for land use decision simpler and more direct. The land area and soil identification can be stored on a cell basis (2.5 acres) followed by print-out of interpretive features in a map form. An advantage of the system is the ability to interpret for a large number of potential uses from the same source information. Examples are given here of adapting printouts of soil maps data in such way as to evaluate land suitability for homes with septic systems and for determining a base productivity index to underlie assessment of agricultural lands.

Introduction

Land use is a complex problem. Land use decisions sound or otherwise, are being made which are shaping the nature of life in every community and around the country. Some are made without considering the physical land resource suitability. Knowledge of trade-offs between present and future uses needs emphasis to allow sound economic judgments.

The detailed county soil survey is a basic inventory of soils and their properties. Soil surveys provide physical information of unique value to help decision makers even though they are complex to use and to understand. Detailed soil maps can be make more useful by evaluating soils for combinations of factors which contribute to success of various land uses. For example, soil drainage class (presence or absence of seasonal high water table) can influence suitability of an area for septic system usage. Slope and other soil characteristics affect agricultural productivity.

Computer methods can make the use of soil maps for land use decisions simpler and more direct. Detailed soil maps can be stored in the form of dominant soil symbol per unit cell in the computer. Then along with soil data files, these maps can be used to evaluate every soil map unit in a county. Rapid evaluation can be made for a large number of uses, like agricultural land assessment and septic suitability. This article describes the methodology used for soil map and data storage and the method of display and interpretation of the maps.

Soil Map Preparation

The computer is an effective tool for storing, analyzing and displaying resource data which can guide policymakers toward rational selec-

tions among land use alternatives. The computer has further advantages in terms of speed, accuracy and cost of interpretations.

First it is necessary to create a soil data bank. This includes all the soil series mapped in the state of Indiana. Each soil series has specific characteristics in terms of texture, drainage, organic matter content, productivity index, etc. Such information is recorded for each soil series, punched on computer cards, and stored in the computer memory system as a soil data bank.

Then it is necessary to prepare location data information. This is obtained from the detailed county soil survey map. This is done on a square-mile basis from the county soil survey map or from advanced atlas sheets if a county does not have a published soil survey map. A photograph of a particular section (one section will be equal to one square mile) is taken with a transparent grid laid over the map. The grid has 16 rows and 16 columns giving a total of 256 cells per section. Each cell is 2.5 acres in size, a unit about equal to the smallest soil areas separated in field mapping by soil scientists. From the enlarged photograph, the dominant soil symbol is identified and recorded on data sheets. Computer cards are punched with identification of county name, township, range, section, row and column. This information is assembled in a location data file and stored in the computer memory system.

Interpretation for Residences on Septic Systems

One can use soil data bank and location data file information to evaluate a variety of community plans or needs, as requested. For example, let us assume that a local community is interested in evaluating a residential area for septic systems. It is necessary to write or to formulate a computer program for interpreting the suitability of specific location data for residential areas using septic tanks, taking into consideration the factors developed for engineering interpretation by Soil Conservation Service. Surface texture, texture of the control section (family), natural drainage, stoniness, depth of bedrock, topographic position, and slope of the soil are the factors under consideration to formulate a rating system on the basis of soil limitations. One devised for trial in Indiana rates 100-88 as slight, 87-76 as moderate, and below 75 as severe limitation. So an overall index is constructed taking into consideration all of the factors for residential interpretation. This program will interact the location data file and the soil data bank to set an index value for each cell (2.5 acres) in a square mile area for residential interpretation. A simulated computer printout is given in Table I. A high numerical rating indicates slight limitations and more acceptability for residential sites with septic systems. Also in the table other features could be located. A flood plain in this example has been specified as '777' and the area under a lake specified as '666'. In this example, the values in column 16 are specified as zero because the cells fall partly outside that section hence are not considered for residential interpretation. If a county were able to provide printouts for all sections those would provide a rapid evaluation to potential use for residences on septic systems. By similar methods a wide variety of interpretive printouts could be made for other com-

TABLE 1. This table represents an index value for residential homes with septic filter, fields—no basements. Each cell in the table below represents an area of 2.5 acres. A value of 100 would be the most suitable site based on natural physical features. A value of 111 indicates the area is 100 percent urban. A value of 222 indicates the area is highway or road. A value of 333 indicates the area is an organic soil. A value of 666 indicates the area is a lake or pond. A value of 777 indicates the area is subject to flooding.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	777	73	73	63	51	777	777	73	73	63	63	63	63	63	777	0
2	777	777	777	777	73	73	73	51	73	777	777	63	63	63	51	0
3	777	777	777	777	666	666	73	73	73	777	777	777	51	51	63	0
4	777	777	777	777	777	777	777	777	777	777	777	777	777	777	777	0
5	73	73	73	777	63	777	777	777	777	777	777	777	777	777	777	0
6	73	32	51	51	73	777	777	777	777	777	777	777	777	777	777	0
7	73	73	32	51	63	63	777	777	777	777	90	90	777	777	777	0
8	73	73	73	73	73	73	63	777	777	777	51	51	51	777	777	0
9	32	32	32	51	51	63	63	73	73	63	51	63	63	777	777	0
10	51	51	32	51	51	73	51	73	51	51	73	51	73	777	777	0
11	51	51	51	51	51	73	51	51	32	51	73	73	73	777	73	0
12	32	51	32	51	51	51	32	51	51	51	73	63	777	777	73	0
13	51	51	32	51	32	51	51	51	51	51	73	63	51	777	777	0
14	73	51	51	51	32	32	32	51	51	51	73	63	51	777	777	0
15	32	51	51	32	51	51	51	51	32	51	63	63	46	46	777	0
16	51	51	51	51	32	51	32	32	32	63	63	73	63	63	777	0

munity development decisions (rating sewage lagoons, sanitary landfills and roads etc.).

Agricultural Land Assessment

A modern soil survey can be used as a guide for land assessment for property tax purposes. This use of the soil survey can provide a high return on the investment a county has made in obtaining their survey. The soil survey rates the productive capacity of land but does not determine the final valuation of land. Valuation is the province of the local assessor and soil ratings provide only a guide. The use of the survey for assessment is appropriate only for agricultural land; land under urban uses has values based more on buildings and locations. A computer method of land assessment furnishes a uniform and economical means of judging the potential productivity of land in a county; it is easily explained and defined resulting in fewer complaints, it reduces the influence of good or poor production practices on land evaluation, and the computer system speeds up the process and reduces costs.

Conditioned by weather, the physical properties of soil (moisture holding capacity, drainage class, slope, etc.) contribute to produce a given range in yield, year in and year out. By evaluating these soil properties, we can rate soils in terms of a 'capacity to yield' under a given set of climatic and management conditions. One has to consider the ability to produce a yield but also should consider the costs necessary to achieve this yield. So the rating used is called Productivity Index or PI ($PI = \text{gross return} - \text{production costs} - \text{conservation costs}$). The PI seems to be preferable to yield estimates since it includes costs necessary to obtain the production and recognizes that high yield costs more on some soils than on others. The PI also recognizes the fact that all soils cannot be cropped with similar intensity.

Assuming we consider the same section of land we have just discussed (in interpretation of residences) as one square mile of agricultural land. The soil data bank and the location data file will be the same. In land assessment it is necessary to create an ownership file. The land-owners name is recorded by county, township, range, section and by rows and column. There may be several owners in a section. All this information is transferred to computer cards to create the ownership file. Through a computer program for each owner in a section, the computer reads the soil symbol in each cell, looks up the PI for each, adds them up and finds out the average PI (average $PI = \text{adding all the PI in a parcel land and dividing by the number of cells a farmer owns}$) for each parcel of land or farm. Then the computer prints out a list of PI values for each cell in a section and also prints out the name of the owner and his average PI in the parcel of land. Simulated computer print outs are given in Tables 2 and 3.

These productivity indices can form the basis for improved agricultural and open land assessment. This gives a local assessor a ready opportunity to equate the soil resource of one farm to that of another. It also provides the county assessor with information for comparing

soil resources throughout the county. The State Tax Equalization Board can use this kind of information in tax equalization between counties and school districts.

TABLE 2. *Land Ownership Information*

Name	Acres	Average PI
Farmer X -----	100	58.8
Farmer XX -----	30	41.7
Farmer XXX -----	125	52.8
Farmer Y -----	10	34.5
Farmer YY -----	20	54.9
Farmer YYY -----	50	54.2
Farmer Z -----	100	60.3
Farmer S -----	10	56.0
Farmer P -----	40	55.6
Farmer Q -----	60	63.0
Farmer N -----	55	48.1

An individual farmer or farm manager can utilize these productivity indices in his management planning. By knowing the different soils on his farm, the operator can compare his current net crop return with the potential net return (PI) for each soil. This would assist a farmer in planning for the most efficient management of his land. For example, improvement of a tile system on a given soil may or may not provide enough benefit to cover the cost of the improvement.

Another use for these values is in land appraisal. Using soil surveys, a farm appraiser can determine the acres of different soils on a given farm, then using the productivity indices, one can find an "average PI" for them. The same procedure can be used for other farms recently sold in the area. All this can help establish the fairness of price for land.

Times are changing and the demand on our land resources are increasing. Computer methods of handling the soil property information make soil map usage for land use decisions simpler and more direct. The scientific method of using a soil data bank with a modern electronic computer can aid community planners to make sound land use decisions. Another advantage of the system is the ability to interpret for a large number of potential uses from the same source information.

TABLE 3
P.I. VALUES IN THE CELLS BY FARM OWNERSHIP

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	80	34	34	12	56	80	80	34	34	12	12	12	12	12	80	0
2	80	80	80	80	34	34	34	56	34	80	80	12	12	12	5	0
3	80	80	80	80	0	0	34	34	34	80	80	80	5	5	12	0
4	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	0
5	34	34	34	80	12	80	80	80	80	80	80	80	80	80	80	0
6	34	69	56	56	34	80	80	80	80	80	80	80	80	80	80	0
7	34	34	69	56	12	12	80	80	80	80	65	65	80	80	80	0
8	34	34	34	34	34	34	12	80	80	80	56	56	56	80	80	0
9	69	69	69	56	56	12	12	34	34	12	56	12	12	80	80	0
10	56	56	69	56	56	34	56	34	56	56	34	56	34	80	80	0
11	56	56	56	56	56	34	56	56	69	56	34	34	34	80	34	0
12	69	56	69	56	56	56	69	56	56	56	34	12	80	80	34	0
13	56	56	69	56	69	56	56	56	56	56	34	12	56	80	80	0
14	34	56	56	56	69	69	69	56	56	56	34	12	56	80	80	0
15	69	56	56	69	56	56	56	56	69	56	12	12	73	73	80	0
16	56	56	56	56	69	56	69	69	69	12	12	34	12	12	80	0

TABLE 3. P.I. Values in the Cells by Farm Ownership.

Coprogenous Earth in Organic Soils of Northern Indiana¹

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and

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Abstract

Coprogenous earth is one of the materials that occur in old lake bed sediments below organic soils. In Northern Indiana this material has a wide range of properties. It either forms a slightly viscous suspension and is slightly plastic but not sticky, or it shrinks upon drying to form clods that are difficult to rewet and that tend to crack along horizontal planes. The organic matter content is low and it has low shear strength. Where this material is exposed on or near the surface the soil may be less desirable than organic soils for pasture or cropland. As the organic materials on the surface oxidize or blow away, the underlying coprogenous earth will become more important as a constituent of the soil, creating problems in using these soils. Special precautions should be taken to preserve organic soils where they cover coprogenous earth deposits.

Introduction

The first stage in the development of an organic soil is the deposition of organic and inorganic sediments at the bottom of a lake. These sediments are called *ooze* by limnologists (Rutter, 1963). They may form in the lake itself by life processes or physical-chemical processes separating them from the water, or they may be introduced from outside the lake by inflowing water, falling of dust, etc. Whether the sediments are primarily derived from within the lake or from outside depends on the nature of its watershed. The organic components of the *ooze* originated from plankton (free-water organisms) that settle to the bottom and then, along with other sediments, are reworked by bottom animals and bacteria.

Through deposition of sediments, a lake becomes continually shallower and the shore flora continually advances farther towards the center of the lake and finally covers its entire surface. In this second stage in the development of the organic soil, filling-in is accelerated by production of large quantities of plant material which forms bog peat.

In soil morphology and classification (Soil Survey Staff, 1975), this peat and its more decomposed form, muck, are recognized as organic soil materials and the *ooze* of limnologists is called limnic sediment. Organic soil materials contain more than 12 to 18 percent organic carbon (20 to 30 percent organic matter), depending on the clay content of the mineral material, and are subdivided according to

¹Journal Paper No. 6095, Purdue University Agricultural Experiment Station.

degree of decomposition into fibric (least decomposed), hemic, and sapric materials. The degree of decomposition is determined by two tests: the amount of fibers remaining after manipulation of the material and the color of a sodium pyrophosphate extract. Pyrophosphate dissolves dark-colored humic materials formed when peat decomposes.

Limnic sediments are subdivided into diatomaceous earth, composed of the siliceous remains of diatom organisms; marl, composed mainly of CaCO_3 ; and coprogenous earth (formerly called sedimentary peat or colloidal muck) which contains significant amounts of fecal pellets. Some limnic sediments also contain enough organic matter to be included with organic soil materials.

In Indiana there are about 500,000 acres of organic soils mostly in the sapric (muck) or hemic (peaty-muck) condition. This area is about equivalent to the area of two counties. The underlying sedimentary deposits have not been well studied. We have not seen diatomaceous earth sediments in the state, but have identified marl and coprogenous earth.

The purpose of this paper is to characterize the morphology of organic soils that contain coprogenous earth sediments and to discuss problems that may arise in using these soils.

Methods and Materials

Several sampling sites were selected to represent soils that we believed contained coprogenous earth layers. They were described (Soil Survey Staff, 1951 and 1975) and sampled from pits about 4 or 5 feet deep and from deeper auger samples. In the horizon designations, the first letter is "O" for organic soil materials, "L" for limic sediments, and "A", "B", or "C" for mineral soil materials. The lower case characters represent a subdivision of the major horizons—"a" for sapric, "e" for hemic, "co" for coprogenous earth, and "p" for a surface plow layer. A number may also be used to further subdivide thick layers. Roman numeral II represents a major change in parent materials.

For a few horizons, a soil smear was made by mixing a small amount of the material with water and spreading it thinly on a microscope slide. After it dried a cover glass was mounted with clear epoxy cement.

Shear strength was determined with a vane-shear apparatus (McKinzie et al., 1975).

W. C. Lynn and W. E. McKinzie also collected samples for chemical and physical characterization at the national Soil Survey Laboratory.

Results and Discussion

Soil Descriptions

Soil 1

Location: Montgomery County—2100 feet W and 1320 feet S of NE corner of Sec. 34, T20N, R4W.

Size of Area: 640 acres; vegetation-corn

Description:

Oap—0-28 cm (0-11") black organic matter (N 2/0) (sapric); moderate medium granular structure; very friable; neutral.

Oa —28-66 cm (11-26") dark reddish brown (5YR 3/2) organic matter (sapric); moderate very coarse prismatic structure; friable; neutral.

Lco—66-183 cm (26-72") very dark grayish brown (10YR 3/2) and olive gray (5Y 4/2) coprogenous material; massive, soft, non-sticky, non-plastic, slight rebound when compressed, gelatinous; neutral above 94 cm and moderately alkaline below. Fine sand layer at 94-99 cm.

Lco and Cg—183-326 cm (72-130") similar to above horizon except that gray fine sand horizontal bands 2 to 5 cm thick occupy about 20 percent of the horizon.

Remarks: A vertical wedge shaped projection 15 cm wide at 28 cm and coming to a point at 94 cm filled with organic material similar to that in the plow layer was observed on both sides of the pit. This cracking indicates high shrinkage of materials at these depths. Other thinner crack fills were also observed. The fine sand layer at 94-99 cm conducted water into the sampling pit. Apparently this layer facilitates drainage of the soil.

Soil 2

Location: White County—1420 feet S and 485 feet W of NE corner of Sec. 3, T27N, R2W.

Size of Area: 40 acres; vegetation-corn

Description:

Oap—0-23 cm (0-9") black (N 2/0) organic matter (sapric); moderate medium granular structure; very friable; neutral.

Oa2—23-40 cm (9-16") dark reddish brown (5YR 2/2) organic matter (sapric); weak thick platy structure; very friable; neutral.

Oa3—40-70 cm (16-28") black (10YR 2/1) organic matter (sapric); moderate thick platy structure; firm; neutral.

Lco—70-176 cm (28-70") dark gray (5Y 4/1) coprogenous material; weak coarse platy structure in the upper part and massive below 176 cm; firm, soft, smooth, slight rebound when compressed; non-plastic, not sticky, strong effervescence; moderately alkaline.

Remarks: Material between 176 and 450 cm is olive (5Y 5/4) and has strong effervescence. It appears to be marl.

Soil 3

Location: White County—1320 feet W, 300 feet N of SE corner of Sec 1, T28N, R5W.

Size of Area: 160 acres; vegetation-grass.

Description:

Ap —0-23 cm (0-9") very dark gray (10YR 3/1), silt loam high in organic matter; moderate medium granular structure; friable; some evidence of burning of organic layer; neutral.

Lco—23-41 cm (9-16") dark gray (5Y 4/1) silt loam; weak very coarse subangular blocky structure; smooth, non-sticky, non-plastic, firm, strong effervescence; moderately alkaline.

IIBg and Cg—41-152 cm (16-60") gray (10YR 5/1) fine sand; strong effervescence; moderately alkaline.

Remarks: This profile represents several hundred acres of soil observed in White County. The material between depths of 23-41 cm has characteristics of coprogenous earth. It is somewhat more weathered than that observed in thicker deposits.

Soil 4

Location: Cass County—SE $\frac{1}{4}$ of NE $\frac{1}{4}$ of Sec. 6, T27N, R1W.

Size of Area: 40 acres; vegetation-corn.

Description:

Oap—0-28 cm (0-11") black (N 2/0) organic matter (sapric); moderate fine granular structure; very friable; slightly acid.

Lco—28-58 cm (11-23") very dark grayish brown (10YR 3/2) and dark brown (2.5Y 4/2) coprogenous material; moderate medium platy and weak medium angular blocky structure; firm, slight rebound when compressed, smooth, non-sticky, non-plastic; evidence of shrinkage on drying. V-shaped wedges filled with surface material; neutral.

IIC—58-150 cm (23-60") pale brown fine sand; single grained; loose; strong effervescence; moderately alkaline.

Remarks: The material below 28 cm and above 58 cm has characteristics of coprogenous earth. Part of the coprogenous earth is being turned up on the surface when plowed. When dried it rewets slowly. There is evidence of difficulty in turning with the plow. Large hard flakes occur on the surface.

Soil 5

Location: LaPorte County—1980 feet W and 1320 feet N of SE corner of Sec. 32, T35N, R3W.

Size of Area: 80 acres; vegetation-corn.

Description:

Oap—0-26 cm (0-10") black (10YR 2/0) organic matter (sapric); weak fine granular structure; very friable; very strongly acid.

Oe —26-40 cm (10-16") reddish brown (5YR 4/3) partly decomposed organic matter (hemic); moderate thick platy structure; friable; strongly acid.

Lco1—40-198 cm (16-78") very dark gray (10YR 3/1) and dark gray (5Y 4/1) coprogenous material; moderate, thin to thick platy structure; soft, smooth, non-plastic, non-sticky, rubbery like, moderate rebound when compressed; neutral to 64 cm and moderately alkaline below; carbonates occur as short white threads and fine skeletal remains.

Lco2—198-228 cm (78-90") gray (N 5/0) coprogenous earth and marl; massive; slightly sticky; violent effervescence; moderately alkaline.

IIC—228-254 cm (90-100") gray (N 5/0) fine sand; single grained; loose; violent effervescence; moderately alkaline.

Remarks: Material in this profile between depths of 40 cm and 198 cm has the characteristics of coprogenous materials. Wedge shaped crack fills 7 cm wide at 40 cm and tapering to a point at 89 cm are filled with black organic material from the surface. The filled cracks indicate high shrinkage of the material at a time when the soil was dry.

Soil 6

Location: Steuben County—2500 feet W and 1500 feet S of the NE corner of Sec. 2, T37N, R14E.

Size of Area: 160 acres; vegetation-mint.

Description:

Oa —0-73 cm (0-29") black (10YR 2/1) and very dark brown (10YR 2/2) organic material (sapric); very friable; granular on the surface and weak coarse platy below; very friable; neutral.

Lco—73-187 cm (29-75") dark grayish brown (2.5Y 4/2) and olive gray (5Y 4/2) coprogenous material; weak very thick to thin platy structure; firm, soft, smooth, gelatinous, greasy feel, slight rebound when compressed; moderately alkaline (many fine white calcareous threads and fine shell remains).

IIC—187-200 cm (75-80") gray (5Y 5/1) coarse sand; single grained; loose; violent effervescence; moderately alkaline.

Remarks: Landowner indicated that the surface is about 40 inches lower than it was originally before drainage. Present owner has farmed this area since 1934. It was originally drained about 1900. A row of willows planted as a windbreak shortly after 1900 have a diameter at the base of about 130 cm (52"). Materials between depths of 73 and 187 cm have characteristics of coprogenous material.

Soil 7

Location: Steuben County—3100 feet W and 3000 feet N of SE corner, Sec. 23, R14E, T38N.

Size of Area: 300 acres; vegetation-corn.

Description:

Oa —0-38 cm (0-15") black (10YR 2/1) organic matter (sapric); moderate fine granular structure on the surface and moderate thin to thick platy below; very friable; soft; strongly acid.

Lco—38-177 cm (15-70") very dark gray (10YR 3/1) and dark gray (5Y 4/1) coprogenous material; weak thin to thick platy structure; firm; non-sticky, non-plastic, slight rebound when compressed, gelatinous, greasy feel; neutral.

IIC—177-225 cm (70-90") gray (N 5/0) clay; massive; very firm, sticky and plastic; strong effervescence; moderately alkaline.

Remarks: Few seed pods and grass stems in the coprogenous material. V-shaped crack fills are 2 to 3 cm wide at 42 cm and wedge

out at 80 cm. They are filled with organic material from the surface. These cracks indicate high shrinkage when the coprogenous materials were dry.

Microscopic Examination

Soil 1, Lco horizon, 75 cm depth: Mainly angular quartz grains plus a few calcite, feldspar, and other mineral particles, mostly in the size range 10 to 50 μm . Large fragments of organic fibers and aggregates of organic matter around 200 to 1000 μm and numerous small shreds of organic matter.

Soil 2, Lco horizon, 120 cm depth: Mineral portion is almost entirely calcite grains, mainly 2 to 20 μm in diameter, that are roughly equi-dimensional in size and irregular in outline. Many larger brownish aggregates of organic matter with diffuse edges. A few isotropic small animal remains, around 10 to 100 μm , and a few calcite shell fragments.

Soil 7, Lco horizon, 100 cm depth: Matrix is light yellowish brown jell. Within the jell are irregular shreds of plant tissue; round, opaque particles 10 to 40 μm in diameter that are brown to black in reflected light (fecal pellets); angular quartz grains and rounded calcite grains 10 to 100 μm in diameter; and a few isotropic skeletal remains of small animals.

Physical Properties

Field tests show the shear strength of the coprogenous material to be very low. It ranges from 50 to 100 pounds per square foot compared to 150 to 300 pounds per square foot for organic materials and 400 to 600 pounds for a representative clay loam.

Shrinking characteristics are illustrated by a field test on Soil 7, horizon Lco. A block of moist soil $2.5 \times 4 \times 9.5$ cm was carved out and allowed to dry. When it was air dry it measured $1.3 \times 2 \times 4.8$ cm, representing 13% of the original volume.

Discussion

Coprogenous earth is defined in Soil Taxonomy (Soil Survey Staff, 1975) as a limnic layer that

(1) Contains many fecal pellets a few hundredths to a few tenths of a millimeter in diameter; (2) Has a color value, moist, < 5 ; (3) Either forms a slightly viscous water suspension and is slightly plastic but not sticky or shrinks upon drying to form clods that are difficult to rewet and that often tend to crack along horizontal planes; (4) Is normally but not necessarily nearly devoid of fragments of plants that can be recognized with the eye; and (5) Yields a saturated sodium pyrophosphate extract on white filter paper that has higher color value and lower chroma than 10YR 7/3 or the cation exchange capacity is < 240 meq per 100g of organic matter (measured by loss on ignition) or both.

These layers have a range in particle size and a C-N ratio (12 to 20) that are consistent with advanced decomposition. They have both a low and a narrow range in cation-exchange capacity

(80 to 240) meq per 100g of organic matter by loss on ignition which indicates little decomposition influenced by exposure to air. In places these layers show a platy structure. Olive or olive brown colors of organic layers of organic soils are characteristic of coprogenous earth layers. The common colors are Munsell hues 2.5Y or 5Y, values of 3 or 4, and chroma of 2.

The horizons designated Lco meet the field-identifiable parts of the definition of coprogenous earth. The three horizons observed with the microscope, however, vary greatly in their characteristics.

The Lco horizon of Soil 1 consists mainly of silt-size mineral particles carried into the lake from the watershed and mixed with organic materials.

Soil 2 consists mainly of CaCO_3 grains. It would qualify as marl in Soil Taxonomy except that its color (5Y 4/1) is darker than the required color value of 5 or more. The material below 176 cm would qualify as marl. Marl deposits consist of calcite precipitated by the photosynthetic activity of plants as they remove CO_2 or HCO_3^- from dissolved bicarbonates and of shells and shell fragments of snails (Ruttner, 1963). It is usually deposited in the shore zone of lakes rather than in deep water. In Soil 2 it appears that photosynthetic precipitation is the most important factor because of the small size of calcite particles and low content of shells.

Soil 7 has layers most like the definition of coprogenous earth. It contains some round, dark bodies, probably fecal pellets, but they did not comprise a large proportion of the material. It also has some of the characteristics of *gyttja* (Ruttner, 1963), namely the grayish-brown color and the elastic consistency.

From this limited number of microscope observations it appears that coprogenous earth includes a wide range in materials. Perhaps similar materials could be grouped together better if the definitions were modified. The definition of marl could be based on CaCO_3 content rather than color. Then horizons such as the Lco of soil 2 would be called marl instead of coprogenous earth. Because of the importance of the unique physical properties of layers such as the Lco of soil 7 they could be placed in a separate class using shrinking on drying as a differentiating characteristic. There still would be a need for a "catch-all" class to include materials that do not have distinctive characteristics, but this class could be defined so that it is less inclusive than the present coprogenous earth class.

Some materials identified as coprogenous earth have such low shear strengths when moist that they cannot support the weight of wheel tractors, and cattle may sink into them. We have observed that when they are plowed and allowed to dry the clods do not wet-up again very readily.

These properties present obvious problems for using coprogenous materials for growing crops or grazing. In cultivated areas, the thickness of the organic soil material over limnic sediments is being reduced gradually by compaction, oxidation, and wind erosion. In this study, estimates of subsidence since the areas were first drained range from

50 cm (20 inches) to 125 cm (50 inches). It is apparent that measures should be taken to preserve the organic soil overlying the coprogenous earth materials if the soils are to continue to be used for agriculture.

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Historical Highlights in Indiana Soil Science

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Abstract

Within just a few years of de Saussure's identification of aluminum in plants in 1905, S. D. Conner and Associates were studying aluminum toxicity in Indiana soils. Their publication in 1913 is recognized as the first identification of aluminum toxicity in soils in the United States. These studies led into the work of G. N. Hoffer on heavy metal accumulation in corn stalks which in turn became the basis for the Hoffer Corn Stalk Test as a diagnostic aid. Continued developmental work culminated in the introduction of the Purdue Soil and Plant Tissue Test Kits in the early thirties.

T. M. Bushnell introduced the use of aerial photography into soil survey in the early twenties. His development of the catena concept was a major step forward in soil survey. George D. Scarseth's revolutionary research on nitrogen nutrition of corn and other crops initiated a whole new era of increased productivity for soils around the world.

Introduction

It is a general human trait to take the present situation as something obvious and normal and to overlook completely how this situation has come about. In the words of Isaac Newton on his deathbed: "If I have seen farther than others, it is by standing on the shoulders of giants." Actually we stand on the shoulders of those that have gone before us and who have contributed to the development of the physical, social, emotional, and the scientific environment in which we live and operate. This is good, so we should not be burdened with gratitude or disgust for those that have preceded us in our brief sojourn on earth. Nevertheless, it seems appropriate at times to recall the development in the main field of our interest and endeavors. This will show us at what spot we ourselves entered the scene and to give us perspective in planning for our future activity.

This is the reason that we are presenting some of the historical highlights in Indiana soil science.

Potassium

Some of the black soils of the swampy region of Northern Indiana proved to be unproductive, even after they were properly drained. Some of these soils were mucks and peats, others were sandy with enough admixture of humus to make them dark.

In 1892 Henry A. Huston (9) started to investigate the reasons for the infertility of this so-called "bogus" soil and how it might be made productive. His chemical analyses convinced him that the soils were well endowed with nutrients, even though they were not available to the plants. He conducted field experiments on drained "bogus" land, applying potassium fertilizer, lime and straw. The rates per acre were approximately 5 tons of lime, 250 lbs of K_2O and enough straw to contain around 150 lbs K_2O . He found that the application of both the potassium salts and of the straw resulted in large yield increases,

actually changing the useless soil into a very productive one. Huston also recognized that drainage was an important aspect of the infertility of this soil, for he states: "The use of straw or Kainit has proved very profitable as a means of *temporary* improvement of such lands. The *permanent* improvement of such lands must be effected by *efficient* drainage."

To make more certain about these findings, Conner and Abbott (7) conducted extensive fertilizer experiments with corn and onions in ten counties from 1904 to 1911.

It turned out that in most cases, potassium fertilization resulted in the greatest increases in yield. Phosphate application was a distant second. Evidently it was not assumed that nitrogen fertilizer was important on these black soils. Only in a few cases was nitrate of soda used in the experiments. Manure and dried blood were other sources of nitrogen. The result of this work was that the once useless black soils of northern Indiana became highly productive and gained greatly in land value, mainly through generous application of potassium fertilizer.

Aluminum

One of the early achievements in soil investigation was the discovery of toxicity of soluble aluminum compounds in the soil and of the methods of control within a few years after de Saussure identified aluminum in plants. Abbott, Conner, and Smalley reported in 1913 on some unproductive soils in the Kankakee marsh region (1). They found fairly large amounts of aluminum nitrate in these soils. While earlier investigators had noted that aluminum salts in water cultures were toxic to plants, the work by the Indiana scientists was the first that showed that this situation occurs also in the field (12). The soils were very acid, but as the studies were made before the introduction of the "pH" concept in chemistry, we do not have a quantitative report on the intensity of the acidity of the soils in question. The reclamation of these soils was accomplished by a combination of drainage and the application of lime and fertilizer. The calcium and magnesium of the lime, by neutralization of the acids, precipitated the aluminum in the soil solution and decreased the activity of the exchangeable aluminum.

Plant Tissue Tests

Interest in determining plant nutrients in soils and plants dates from 1903 when Jones and Huston (10) conducted an experiment with corn to determine the composition of its various parts throughout the growing season. This gave information not only on the amounts of nutrients needed by the plants but also the rate at which these nutrients have to be available to enter the plants. These investigators stressed "the importance of a continuous and abundant supply of plant food from the time of planting to the time of harvesting the maize plant."

The next logical step was taken by Hoffer (8). He developed a number of chemical corn stalk tests for nitrate and for potassium in the plant and described nutrient deficiency symptoms. The interpretation of the tests and the appearance of the corn plants gave an indication of the nutrient status of the plant and the need for fertilization

of the soil. For the nitrate test he used diphenylamine dissolved in 75 percent sulfuric acid. This reagent is still employed today for this purpose. Hoffer found that "when corn plants grow in soils without adequate available potassium, iron compounds accumulate in the joint tissues." For this reason he used a test for ferric iron in the nodes of the corn plants to determine whether there was a deficiency of potassium in the plant.

Later on Thornton, Conner, and Frazer (15) developed direct tests for potassium and also for phosphorus in plant tissues. The reagents were the same as those used to test soils for these elements. A soil and plant tissue test kit was developed in 1934 that has been used and still is being used without any essential modification. More than 10,000 such kits have been sold all over the world and have helped in the advance of fertilization methods in many countries.

Phosphate Fertilizer

Early in this century the problem of the most economical phosphate fertilizer had not been settled by the agronomists. In 1904 Wiancko and Conner (16) set out to determine whether raw rock phosphate or acid phosphate (superphosphate) would give better results. Extensive field experiments with corn were conducted during several years. The investigations found that "the per acre net profit has been seven times as great from acid phosphate as from rock phosphate. The value of the crop increase per pound of phosphorus applied has been 28.3 cents for acid phosphate and 3.5 cents for the rock phosphate." These results should have settled this problem once and for all. But in our neighboring state of Illinois Cyril Hopkins maintained that rock phosphate was economically superior to acid phosphate. Because of his reputation as an outstanding leader in soil fertility investigations, the controversy raged another 40 years until it was finally laid to rest during the 1950's.

Fertilization Rates that Meet Crop Needs

While experiments with commercial fertilizers were conducted in Indiana during the last quarter of the nineteenth century, their use in general agriculture in Indiana before 1900 was minimal. Discussing the cultivation of sugar beets in 1894, Henry Huston, soil chemist at the Purdue University Agricultural Experiment Station, comments: "Little has been done in America in experimenting with commercial fertilizers on beets. Such experimental facts as have come under my observations seem to indicate that the results obtained did not justify the cost involved." Phosphate fertilization in Indiana became general at the beginning of the current century. Potash and nitrogen followed around 1915. But the rates used were very small. During the Great Depression of the thirties fertilizer use was all but abandoned (11). Even in the more prosperous years that followed, fertilizer rates for corn were in the order of 125 lbs. of 2-12-6 per acre. In the early forties during July and August most corn in Indiana showed severe nitrogen deficiency symptoms. Scarseth reasoned that the lack of success of earlier nitrogen fertilization experiments was due to several causes. In some cases the amount of nitrogen used in the experiments was so

small that it only stimulated vegetative growth and was used up before the ears were formed. In those years fertilizer was usually applied with the corn planter in the row. Substantial rates of fertilizer near the seed create a high osmotic tension and reduce its viability. On the other hand nitrate nitrogen is readily leached beyond the reach of the roots, especially in a wet year, and therefore is lost to the plant. Because of the erratic responses of these early nitrogen experiments, nitrogen fertilization was not recommended in amounts that would meet the crop's requirement.

In this environment Scarseth reasoned that if ammonia types of nitrogen were placed deep in the soil (5 to 9 inches) the nitrogen would remain absorbed on the clay and be taken up by the corn in late July and August. Experiments in '39 with ammonium sulfate broadcast and plowed under confirmed his hypothesis. In many experiments corn yields were increased from less than 30 bushels per acre to over 90 bushels per acre—an unbelievable increase in yield (14)!! These results stimulated the great transformations in crop production systems and fertilization. Fortunately, simultaneously, World War II ended. Consequently low-cost nitrogen became available at the same time the knowledge on how to use it came into existence. Formerly corn was dependent on manure and legumes in the rotation for nitrogen. Now continuous cropping of corn was not only possible but rapidly became an acceptable practice when used with minimum tillage. The rationale for plowing under of nitrogen also was applicable where large amounts of the other nutrients needed to be applied. It was only logical then to plow under large quantities of P and K on infertile soils. Such plowed-under fertilizer was supplemented with row fertilizers for starter effects. This pioneering work in Indiana had not only national but international impact on the food, feed, and fiber production in the world. Indiana was the first state where farmers generally adopted copious fertilization. Up into the fifties, Indiana used more fertilizer than any of the other states. But soon the evidence of the soundness of this technique became so obvious that it spread to the other states of the cornbelt and eventually to the rest of the country and the world. The yields of our main crops that had shown only very modest increases up to the late thirties have more than doubled in the following quarter century.

Catena Concept

The word catena (Latin for chain) was originally introduced into soil mapping by Milne, working in Africa (13). He used this term with two meanings. In one case it designated a pattern of soils that repeated itself many times and was too intricate to allow for separation of the different soils on a map of broad scale. An example of this is the alternate occurrence of soils on mountain ridges and soils in the intervening valleys. He also used the word catena to describe a group of soils of the same parent material but of differing physiographic location. Bushnell (4) adopted the latter meaning and crystallized the concept of catena. He recognized the effects that waterlevel and degree of slope have on the development of soil profiles derived from similar parent material. He classified all of the soil series of Indiana according

to parent material and drainage profile in the so-called "Key to Indiana Soil" that is a classic of organization (5) and has proven very useful in Indiana and stimulated similar use of the catena concept elsewhere.

Aerial Photographs

Thomas M. Bushnell had done soil work for six years before the First World War. In 1918 he joined the Aviation Section of the U.S. Signal Corps and was trained as an observer. He took many oblique shots of the land with a camera from the plane and recognized the value aerial photographs might have for soil survey. After becoming head of the Indiana Soil Survey, he investigated the possibility of using aerial photographs (3). In 1925 commercial companies quoted \$23 per square mile for the photographs. At that time the rather generalized field work of soil survey cost around \$5 per square mile. For that reason administrators considered aerial photographs too expensive. In 1925 Bushnell together with another surveyor, Mark Baldwin contacted Capt. Goddard at Chanute Field in Illinois and received aerial photographs covering several square miles in the Lafayette vicinity. These were used for experimental soil survey mapping.

Also the National Guard took aerial photographs but most of them were taken at a distinct angle instead of vertically. They therefore distorted the dimensions. An engineer, Coblentz (6), working with Bushnell rigged up a large camera to retake these photographs in order to rectify the scale and to get a planimetrically true picture of the ground. A field party used these maps in 1930 in Martin county. Private companies objected to the competition by government agencies and Bushnell ordered an entire set of aerial photographs of Jennings county in 1929. This was the first soil survey of an entire county that was done on aerial photographs anywhere.

The value of aerial photographs for easy and accurate location has become obvious. Interpretation of aerial photographs with or without detailed ground control has become a valuable aid in soil survey. Soon after the introduction of the use of aerial photographs by Bushnell, civil engineers at Purdue University have made use of them for the study of engineering features of soil (2).

Conclusion

Indiana has been responsible for a good share of the progress in soil science. Only the most obvious highlights of the history of Indiana soil science have been presented here. It is difficult to select those items that are truly highlights as compared to other developments in soil science that may be equally important, depending upon the viewpoint.

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Indiana's Soil Survey Adjusts to Changing Needs

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Abstract

While publishing a total of 90 county soil surveys (9 of which are repeats) in a 73 year history, reports and maps have improved dramatically! A greatly expanding audience is served more efficiently due to links forged between soil scientists and others. Disciplines and the applications these links have encouraged include: geologists—surficial geologic maps; hydrologists—ground water recharge; high-way engineers—soil materials surveys; photogrammetrists—locating and displaying physical features; soil conservationists—defining soil depletion and needs for better land husbandry; farm economists—assessing farm production potential; and farm planners—capability of lands for cropping and selection of conservation practices. Rapid post WW-2 land use shifts encouraged surveys and their use by: sanitarians and plan commissions—ordinance development; appraisers and assessors—equitable base for land values; ecologists and foresters—vegetative relations and production potential; and farm managers—drainage and irrigation specifications.

An expanding survey program to complete field work for standard soil surveys by 1984 will challenge soil scientists to new innovations in field procedures, report preparation and educational efforts. Only when the challenge is met will the public achieve maximum use of the finished products to the improvement of land-use decisions in Indiana.

Introduction

Soon after beginning of a national soil survey program in 1899, Indiana completed its first soil surveys. Posey county was published in 1902, Madison in 1903 and the Boonville area, Marshall, Tippecanoe, and Scott counties in 1904. Twenty-nine had been completed before 1925. Soil studies were made in order to extrapolate results of experiment station research to farm fields.

By 1916 reports of early field work on rock and superphosphate at the Scottsburg, N. Vernon, Worthington, Wanatah, Bedford and Littles stations were published in Experiment Station reports. Such work, begun in 1904 and later, was related to the soils used where possible and soils names such as Volusia, Knox, and "slashlands" appeared in the reports. While many of the early soil names used have been replaced in later refinements by other names, this process of extrapolation continues today as we identify and map our soils and relate management experiences to them for the gain of farm managers.

This report will outline how surveys, originally made by the USDA Bureau of Soils, cooperatively with either Purdue University Agricultural Experiment Station (AES) or the State of Indiana Department of Geology (or sometimes both), later became functions of other agencies of USDA. Work moved to the Bureau of Chemistry and Soils and its successors the Bureau of Plant Industry, Soils and Agricultural Engineering (BPIS&AE) and Soil Conservation Service (SCS) all cooperatively working with Purdue's AES.

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This report will trace briefly the use of Indiana's soil surveys progressing from an original central purpose to a number of others which were related to changing demands in the use of Indiana's lands. It should help us understand why, after nearly 160 years of the existence of Indiana as a state and 71 years since making its first survey, the Legislature in 1973 laid plans to help complete all field surveys in the standard soil survey format now in use by 1984. This resulted in the State Soil and Water Conservation Committee, a part of the Indiana Department of Natural Resources, entering into partnership with SCS and the Purdue University AES to cooperatively continue and accelerate the soil survey program. It also required that counties continue to contribute a significant share of the costs of their own surveys, a precedent begun in the mid 1960's.

Soil Survey Develops as a Science

We will not attempt to list here the concepts of classification as they have developed in Indiana since these are described elsewhere (2, 5, 8). The contents of a modern soil survey map and report are evident in the Harrison county survey published in 1975 (18). The emphasis in soil survey has always been to locate on maps well defined soil bodies with reasonably homogenous character of surface soil, subsoil, parent material and geologic origin and to describe properties and uses in reports. Bushnell in 1933 (4) said that the work of the soil survey is "to study the different kinds of soils, to describe and classify them; to learn their needs and adaptations and to show by maps the size, shape and location of areas of different soils. This work is published in the form of reports and county maps."

Soil Science Develops Links with Other Sciences Through the Soil Survey

Mapping units in early soil surveys strongly reflected similar geologic formations such as acid till, limy till, alluvium, outwash and lacustrine sediment, loess, limestone, and sandstone and shale. Earliest maps displayed geologic-physiographic formations and a kind of dominant soil condition assumed to occur on each. This was natural since the origin of field soil science and early soil mapping were greatly influenced by the more mature science of geology and was largely carried on by workers trained in geologic and earth sciences. As understanding increased about soils and their morphology and emphasis shifted from maps of general geologic nature to more complex ones recognizing influence of both geologic and morphologic characteristics, a strong link developed between soil scientists and geologists.

While geologic and topographic maps have greatly helped the soil scientist in his mapping program the soil maps have, in later years, been of prime value to geologists. From the soils maps geologists have prepared maps of surficial geology, so important to locating economic mineral deposits and establishing better prediction of groundwater formations and recharge. Since soil science and surficial geology have so much in common each can and is supplementing the other in important ways.

In the 1920's and 1930's soil maps were beginning to find value among soils engineers whose needs depended partly on nature of the soil mantle and partly on underlying geology. Early work done in Michigan (7) and other states soon spread to Indiana (1) as engineers applied soil survey findings to booming highway construction occasioned by the automobile age.

Highway materials surveys were greatly aided also by the use of aerial photos and the interpretations made possible by the fledgling science of photogrammetry which was becoming of so much aid to the soil scientist (3). Field work began in 1929 on the Jennings county soil survey where vertical aerial photographs were used as base maps for the first time in the United States for a complete county.

Cooperation between soil scientists and engineers led to useful comparisons between classifications for soil materials including texture by USDA, and, by Unified and AASHO systems developed by engineers. This encouraged better understanding between the two developing professions to mutual benefit of each. It later led to cooperative sample collection by field mappers for testing soils by engineering labs with results available to both groups.

The first chapter in a soil survey publication devoted to engineering soil properties appeared in the report for Scott county in 1962. Purdue's Joint Highway Research Project (16) uses soil surveys as an aid to develop engineering soils materials maps for Indiana counties. This illustrates once again a link between sciences. At the same time appraisers for highway rights of way make great use of crop yield prediction values of soil surveys to help arrive at fair market prices of rural lands. Farmers are using the same predictions to sharpen their appreciation of yield levels to expect through improved management (10).

Depression Spawned Programs Boost Use of Soil Surveys

Farm Planning use of soil surveys increased from the time of the great depression and continues today. At that time national attention was drawn to the plight of farmers and to declining productivity in land resources due to serious erosion and fertility decline. Land depletion plus low crop price structure was threatening the very continuance of a strong agriculture.

Soil surveys were already becoming very useful in defining the broad farm land problem. In 1933 it was a soil scientist, Hugh Hammond Bennett, well grounded in southern agriculture as well as in soils, who dramatized the plight of the land and its people and helped form the Soil Erosion Service. This agency gathered broad data to better define the problem of land depletion. By 1935 the work resulted in formation of the Soil Conservation Service (SCS) which rapidly developed the tenet of farm planning in accord with capability of the land and later made its service available to the locally organized soil and water conservation districts.

Soil surveys were adopted early by SCS as the means to determine the capability of the land for cropping intensity and to indicate practices needed to maximize production but maintain the soil resource.

This called for more attention to delineations of slope, erodibility and drainage conditions in the field mapping program of the soil survey and resulted in important changes to adapt to these new needs. A conservation survey division was established within SCS to handle the mapping requests for the rapidly developing soil conservation demonstration projects of the late 30's and for the expanding soil and water conservation districts which followed.

Demands increased on the cooperating agencies (BPIS&AE and AES after 1939) during the '40s and '50s to modify their programs of county soil survey aimed at publication for general use. Emphasis of soil scientists was placed mainly on mapping for farm planning so they felt less pressure to publish maps and reports as in earlier years. Maps also became more complex and reports more lengthy so that publication time following field work increased greatly both in Indiana (Table 1) and across the U.S.

By 1953 the functions of soil scientists of SCS and BPIS&AE and AES were recognized as being so similar that soil survey programs were consolidated under one agency (SCS) and remain cooperative with the Purdue University AES under the title "National Cooperative Soil Survey." The links between soil scientists and agronomists and conservation engineers have been greatly strengthened by this effort!

Depression times also called for broad agricultural economic studies to allow predictions of productive potentials of states and regions. Productivity indices were first reported for major crops in the 1938 soil survey of Pike County. These and indices for other counties made possible predictions of regional production at varying planting acreages as well as effects of improved practices applied to the land. They helped policy makers define needs for farm programs some of which involved incentive cost-share payments to farmers to adopt improved practices and price support programs to preserve a healthy agriculture.

Soil surveys were also required as background for approval of any cost-share payments made to farmers through supporting government programs whether inside or outside of soil and water conservation districts.

Expanding Post-WW-2 Land Uses Stimulate Use of Surveys!

As individual wealth and leisure time increased after WW-2 and roads and auto transport improved, more and more people left the utility-serviced towns and cities for unserviced rural areas which we now call the rural-urban fringe. Since soil and geologic facts are needed in building and road construction, as well as sanitation and landscaping, the soil survey received a new boost of interest and survey information was greatly needed to meet new demands (9, 17). Public health officers and their colleagues the sanitarians soon became clients of soil scientists. Construction engineers also increased their interest in using soil reports. Soil characteristics influencing uses for engineering first appeared in the survey report for Scott county 1962. Soil limitations for on-site sewage disposal using septic tanks and tile fields first appeared in the soil survey of Owen county in 1964 and have been included in all later surveys.

Individual housing often involves using lots of lesser area than the smallest units commonly shown on soil maps. Standard surveys are not always adequate to predict on-site sewage disposal suitability. On request of health departments and plan commissions soil scientists of SCS have responded by mapping proposed subdivision lands at greater detail. This has bolstered the local community service function of soil and water conservation districts. The standard survey maps and special reports have enabled counties and cities to gain experience in soil knowledge so that they can develop ordinances guiding use of septic disposal fields by soils. In this way soil science has forged a new link with both sanitary engineering and public health professions and future homeowners will be assured of improved sanitary construction and operation while local governments can plan for more orderly growth.

As tax rates continually escalate there has been greater demand for soil scientists to help assessors use soil surveys in the tax assessment process. Indiana's legislature in 1973 mandated that soil surveys should be used as they become available to assist in land assessment and the State Tax Commission is laying plans to do so for the 1976 reassessment. Because county officials see the economic savings possible by using soil maps in place of traditional methods as well as the equalization function maps can perform, they have responded willingly. Perhaps, more than any other factor this need for assessment has resulted in the state's willingness to become a partner and complete soil surveys by 1984.

Soil science and other disciplines have also been linked over the years to application for such divergent purposes as establishing original vegetative patterns (ecology), applying tree site indices to applicable areas and predicting survival and growth of planted forest trees (forestry), establishing infiltration-runoff predictions for watershed planning (hydrology), and to determine specific drainage specifications by soils and probable response of soils to irrigation (agricultural engineering). These are examples of common usage but there are many others.

To forge these links with other disciplines, a great many changes have been needed in the final soil survey maps and reports and this meant great changes in field mapping and data assembly procedures. More detailed soil studies and improved map making and report drafting have helped reports and maps fulfill new functions as needed. Changes in broad emphasis will be considered next.

Changes in Soil Survey Emphasis to Meet New Demands

1902-22—The First Generation of Reports

Prior to 1922 the survey maps and reports aimed at general description of a county's agriculture and particular adaptations of crops and cropping practices to the soils. Though texture of each important soil layer was indicated by mechanical analysis, only enough description was included to differentiate it from others and no chemical or fertility testing was included. General use of the soil according to its slope, drainage and other conditions was noted and the prevalent crops and livestock produced locally were discussed. There was also a general description

of county development, including roads, markets, schools and other services as well as average land values. These reports were usually very descriptive of a county's soils and agriculture even though they were not able to extrapolate the results of experimental fields precisely. An attempt was made to do so more in reports of the latter part of that era.

By 1922, 26 surveys were completed, in which the average number of mapping units was 12 but ranged from 4 to 30. Map scales were all one inch per mile (Table 1) and time to publish the map and report after field work was usually only one to two years. Very little time was possible to gather interpretative data in the field on such a schedule!

By 1922 management sections written by Purdue AES workers were added as chapters in reports. Most of the practices formerly described with the landscape and soil descriptions themselves were included in these chapters.

From then on there was more attempt to relate experimental results to applicable soils and a great deal more use was made of chemical analyses. Total elements, elements dissolved in strong HCl, and elements soluble in weak nitric acid were reported for soil layers as a general guide to fertility needs. Three layers down to 30 inches were generally analyzed with approximations of organic matter and total pounds of calcium carbonate needed to raise reactions to neutrality. Adapted fertilizer analyses were stressed. Management discussions were arranged around drainage needs, liming, organic matter and nitrogen supplies, crop rotation needs and fertilization practices.

Reports between 1923 and 1943

During this second period, 23 more county surveys were published in which the average number of mapping units rose from 12 prior to this time to 32 with a range from 7 to 75. This reflected a wide variation in complexity of soil patterns across the State as well as variation in intensity of surveys and an expanding knowledge base about soils and adaptations to use. Map scales continued at 1 inch per mile. In this period an average of 5 years elapsed between field work completion and publication so there was much time for interpretive work both in the field and laboratory. Field work using aerial photographs as a base began in the 20's and added greatly to the accuracy of soil maps.

During this period Bushnell (2, 5) and others developed a system of catenal relations in which soils on similar parent material but on differing relief were seen to have features related to their degree of natural drainage. Catenas were named for their well drained member and were given numbers such as 14 for a group of soils related to Miami.

Drainage classes were numbered as follows: I—Poorly drained level; II—somewhat poorly or imperfectly drained; III—moderately well drained; IV—well drained; V—well to excessively drained, (low water holding capacity); VI—excessively drained (steep and shallow soils); VII—poorly drained, gray, depressional; VIII—poorly drained, very dark gray, depressional; IX—very poorly drained, black, depressional and X—

TABLE 1. *Surveys by 10 year intervals, number of mapping units, publication map scales and years for report completion, 1902-1975, Indiana*

Publication Dates	Number Counties	Avg. No. Mapping Units	Range Mo. Map Units	Map Scale: inches per mile	Avg. Years to Publish	Order of Completion by Counties
1902-1910	10	10	4-17	1.0	1	Posey, Madison, Warrick (Boonville), Marshall, Scott, Tippecanoe, Newton, Greene, Marion, Allen
1911-1920	15	13	6-30	1.0	2	Montgomery, Boone, Hamilton, Tipton, Clinton, Delaware, Hendricks, Elkhart, Warren, Benton, Grant, Starke, Wells, White, Porter
1921-1930	11	27	7-55	1.0	5	Lake, Decatur, Adams, Gibson, Clay, Kosciusko, Lawrence, Monroe, Hancock, Putnam, Wayne.
1931-1940	10	35	15-55	1.0	6	Miami, Blackford, Vermillion, Ohio and Switzerland, Randolph, Dubois, Rush, Pike, Washington
1941-1950	14	74	35-112	1.0 or as listed	10	Jennings, Steuben, Knox, Vanderburgh (2.0), LaPorte, Brown, Fulton (1.32), Martin, Bartholomew, Johnson (1.32), Franklin (1.32), St. Joseph (2.0), Morgan (2.65)
1951-1960	7	114	73-178	2.0 or as listed	13	Noble, Cass, Newton ¹ , Carroll, Tippecanoe ¹ , Fayette (4.0) and Union (4.0)
1961-1970	8	112	72-170	4.0 or as listed	5	Scott ¹ (3.17), Owen, Fountain, Madison ¹ , Parke (3.17), Allen ¹ , Pulaski, Perry
1971-1975	15	64	28-100	4.0 or as listed	6	Sullivan, Howard (3.17), Delaware ¹ , Lake ¹ , Spencer, Shelby, Elkhart ¹ (3.17), Clark and Floyd, Daviess (3.17), Hendricks ¹ , Vigo (3.17), Boone, Harrison (3.17), Crawford (3.17)

¹ Second generation survey of this county.

very poorly drained mucks. The numbers 1-0 were used as suffixes following the catena number in developing number legends to use in field mapping. Thus a well drained, brownish Miami was shown as 144 in field mapping while a poorly drained very dark gray Brookston was shown as 148. A textural prefix was used for surface soils other than silt loams. A Miami loam was 5144 and a Brookston silty clay loam was 3148. A Carlisle muck associated with Brookston soils in wet depressions was shown as 140, the zero representing much of drainage class X. All drainage classes were not found in all catenas.

Since this system was used for a quarter century or more all field maps of that period had uniformly numbered legends and persons using maps could obtain a broad concept of soil patterns without extensive reference to descriptive materials.

Improvements in Reports of the 1944-59 Era

During this period even more important changes in soil survey report content and scale of published map occurred! This reflected both changes in soil knowledge and the demands of users when farm planning on a land use capability basis became more common and soil maps were needed to arrive at the capability units. Though farm planning use of surveys began in the '30s the lag in publication time following field work (Table 1) was enough that changes in published reports were not reflected for 10-15 years.

Tables of productive potential expressed as crop productivity indices first appeared in the Pike county survey of 1938. These indices useful to economists were estimated at two levels of input in later surveys such as Vanderburgh. Yields of a county's soils were compared to yields commonly obtained on an extensive soil widely used for the same crop either without amendments (level A) or with combinations of production practices (level B). A soil with potential to produce the crop at standard index levels was assigned a rating of 100. Those more or less productive received proportionately higher or lower indices.

Chapters on morphology and genesis of soils with keys relating soils to formative factors first appeared in Washington county in 1939. These chapters provided a place for soil scientists of these earlier periods to communicate with those who followed as to how they classified the soils and related them to each other. This has been very helpful to later soil scientists.

Outstanding Reports of This Period

One outstanding report of the period is for Knox county (1943) (20) where the first general soil map showing 8 associations appeared with an estimate of how much of each association occurred in the 10 townships of the county. Also included was an estimate of percent cropland devoted to each of 7 crops in these same townships. This recognized the need which many persons have for soil and land use knowledge on a general basis for planning toward broader land use changes.

Perhaps the most innovative report of the period was for Vanderburgh county published in 1944 in which the modern report form began to emerge. Its features included productivity indices at two levels of

management as well as estimated acre yields with normal practices and with combinations of improved ones. This helped set yield goals for farmers to achieve. There was also a chapter on genesis and morphology with a key to soils and a section on naturally occurring vegetation detailing trees, shrubs and grasses occurring on broad drainage groups of soils.

The chapter on soil management in the Vanderburgh report included recommended practices such as drainage and erosion control based on drainage class, slope, and degree of erosion. There was also a table grouping soils as to workability, erodibility and management needs. A general soil map of the county at about 4 miles per inch gave users information on the general nature of the soil landscapes and their overall usefulness.

The map for Vanderburgh was published at a scale of 2.0 inches per mile, the first in Indiana larger than 1.0 inch.

All of these innovations probably reflect a strong interaction of soil scientists with farm planners during this survey of the first of Indiana's soil and water conservation districts. It resulted in a report aimed to help users benefit from knowing about their soils in considerable detail. One hundred and eleven units were separated on the maps.

Reports had similar form up to and including Cass county in 1955. Experimental map scales of 1:48,000 (1.32 inches per mile) were tried in Fulton, Johnson and Franklin in the late '40s and at double that scale (1:24,000) in Morgan in 1950. St. Joseph, Cass and Newton counties were all published at 2.0 inches per mile in the early '50s.

During this period rapid technological change was occurring on Indiana farms resulting from use of combinations of practices and products. Improved crop varieties were being produced with regularity and new and more concentrated fertilizers and other farm chemicals were appearing. Survey reports no longer stressed fertilizers by grade. Instead principles of choice of fertilizers were listed.

Carroll and Tippecanoe reports were published in 1958 during a transitional period to a new era of map display. Maps are in color and at 2.0-inch-per-mile scale with sheets bound into the report each covering some 35 square miles. These reports had useful tables suggesting use and management including rotations for soils of similar management groups. They also had block diagrams to connote soil relations to slopes and parent materials and small scale general soil maps interpreted for single purposes. The first tie-in was made in an Indiana report with the land capability classification system of SCS even though all mapping did not coincide completely with those standards used to define the capabilities. They were the last reports to include productivity ratings by indices.

Era of the Standard Soil Survey Report: 1960 to the Present

In 1960 Fayette and Union counties were published together at 4-inch-per-mile scale (1:15,840) having individual map sheets bound into reports and displayed on a photomosaic base. This allowed users more ease in locating themselves on the soil maps since many visible features could be seen on the air photo base map. Each map sheet covers

about 6 square miles and is bound into the back of the report. In reports with maps at 1:20,000 (3.17-inch-per-mile) there are 15 square miles displayed per map sheet.

The 9x11-inch report size begun with Carroll and Tippecanoe counties was continued and the first general soil map in color and at scale of about 3 miles per inch was included. One table presents a summary of important soil characteristics while another estimated yields for all 149 mapping units for important crops. A table discussed suggested use and management of soils including adapted rotations and was arranged around capability units as used in farm planning.

Following reports had similar format which has continued until now. They include some fairly standard chapters: A general discussion of a county and its agricultural and forestry practices and industry is enhanced with some selected census and climatological data. Soils are described first by the series (Miami) and next by the soil types (Miami silt loam) and phases (Miami silt loam, 2-6 percent slopes, moderately eroded, etc.) which occur on the maps. General use of each soil and its management problems is discussed. Soil management is discussed by capability units with all soils having the same kind and degree of limitation and about the same needs for fertility, drainage and water management practices being in the same management unit. There may be 10 to 20 of these.

Yield estimates for the major crops are given for customary management levels and for levels achieved by use of improved practices. They help define responsiveness of the soils to adapted practices. In counties like Lake, with a large truck crop industry, a report section deals with adaptation of soils to special crops.

Tables of yield potential by forest site classes and a tree planting guide by soils first appeared in the Scott county report in 1962 which also defined types of forest occurring naturally in each soil association area on the general soil map. The Owen county report included the first discussion of wildlife and its management.

Useful Features Added to Meet User's Needs

A number of additions were made in the reports from 1962 till the present. Chapters defining soil properties important to engineering uses appeared first in the Scott county report in 1962. Engineering test data and group classifications for a number of selected soils tested by the Joint Highway Research Project at Purdue University were first added in the survey report for Owen county in 1964. Estimated engineering properties for all soils also first appeared there along with engineering interpretations tables including limitations for use of septic tile fields. These have become of prime value to sanitarians and plan commissions.

The first section on outdoor recreation potential appeared in the report for Allen county in 1969 which also included listings of trees and shrubs useful by soil groups for wildlife, and shelterbelt plantings and for gully and erosion stabilization. The Howard county report in 1971 included the first table of soil limitations for six common classes of outdoor recreational uses.

The discussion of soil limitations for homesites, septic disposal fields, local roads and streets, sewage lagoons, and landfills were first grouped into a section titled "Town and Country Planning" in the report for Lake County in 1972 which also discussed landscaping plants as adapted to soils. An excellent chapter by that name appeared in the Elkhart report in 1974 (15).

The chapters on formation and classification of soils were strengthened and included small maps of underlying geologic formations, along with a discussion of processes of formation and of the classification system used. Representative profiles of each of the great soil groups was described in detail with data on range of characteristics and relations to other soils.

In 1964 the soil series classified according to Soil Taxonomy (Soil Survey Staff 1973) and the 1938 systems of classification (Order, sub-order, subgroup and family of the new Taxonomy vs. Great soil group of 1938) was first included in the Parke county report. These are of primary interest to scientists.

Useful additions to the modern standard reports are tables displayed just ahead of the maps which list mapping units by their capability unit grouping and the pages in the report where descriptive and various management data can be found. These are easily available to the map user. Another helpful addition is a glossary of terms unfamiliar to the layman which appears in the text.

Interpretations Indicate Limitations

In many cases soils have been interpreted by their degree of limitation for use for the intended purpose. A homesite may have a slight, or a moderate or a severe limitation for use for septic tank filter fields which imply the following:

Slight: Relatively free of limitations and any present are easy to overcome. Normal construction costs will apply.

Moderate: Has limitations which may be overcome by careful design and good management. Construction costs will increase, varying according to the kind of limitation to be overcome.

Severe: Has limitations which make use for this purpose questionable and require careful design in construction and superior management during use of the property. Costs may be great enough to suggest that a site with less soil limitations be chosen.

This system of limitations attempts to key the reader to degree of problem. It does not attempt to define a cure for that problem. This is assumed to be the province of other professional people who must use judgments in addition to soil factors in seeking solutions.

Additional Aids to Use of Soil Surveys

In the era of modern standard surveys several other aids have been developed as supplements. Cooperative publications such as the

Key to Indiana Soils (8) furnish a continuously updated list of Indiana soil series mapped in Indiana displayed by parent materials and natural drainage classes.

Special publications on farm planning (6) include management-productivity groups which allow determination of main management needs of Indiana soils grouped according to major limiting factors and productiveness. They also provide updated crop yield goals to supplement those conservative levels reported in earlier surveys. A publication on irrigation for land application of animal wastes (13) uses these same groups and discusses water intake rates and water holding capacities as a guide to potential irrigation rates.

Another booklet (19) lists all Indiana soils interpreted for waste disposal uses not normally included in standard soil survey publications. The Indiana Farm Drainage Guide (14) discusses types of drainage needed and spacing of tile lines, surface water channels and open ditches as adapted by soil groups. It is used by farm planners, contractors and engineers.

Recognizing the value of general soil maps first initiated in Knox county (1943), a set was prepared cooperatively between SCS and Purdue AES in 1971 and was updated in 1975 (12). One association legend was used across the state and maps were finished in one period and at the same scale which allows easy comparison across county lines. Each association was analyzed for a number of factors important to its broad land use pattern, value and management for agricultural and community development (21). These maps and analyses have become powerful tools for planners, appraisers, agribusiness and others having area or state-wide interests. They also help fill gaps where detailed surveys are not yet available.

Modern standard soil surveys are complex and detailed and the reports have to serve many audiences. Experiences in teaching (11) indicate that both individuals and audiences have difficulty in map reading and comprehension of reports. They also find it difficult to locate data from tables and text pertinent to learning the soil problems and the possible solutions for the use in which they are interested.

There is a challenge to develop reports aimed specifically to meet the needs of special user groups but to tie in closely with and supplement the standard survey reports. Such reports could go a step beyond them and offer alternative management suggestions to overcome or decrease the limitations which soils exhibit for various uses. Pioneering such a user-oriented series of reports should logically originate in the universities and be spearheaded by those interested in improving land uses but enlisting support from specialists in many fields.

Systems to put soil data which is read off maps into computer storage are being developed cooperatively with counties (22). This makes possible the recall of information needed by assessors in preparing for updating tax assessment procedures and by others with different reasons to be interested in soils data.

All of these efforts have reinforced the cooperative nature of the soil survey program with Purdue and SCS staff cooperating fully and

enlisting support from others as needed to make our surveys useful to ever widening audiences.

Summary and Conclusions

The changing demands since 1902 intensifying land uses for many purposes has resulted in a gradually changing soil survey. This paper traces a number of changes to illustrate the responses made in several periods—1902-22, 1923-43, 1944-59 and 1960 to the present.

There have been great changes in numbers of soils recognized, numbers of units appearing on maps, and, in the gradual accumulation of soil knowledge which was passed along from earlier years to improve later soil mapping and reports. The greater number of small soil units mapped has called for gradually enlarging map scale.

Farm planning uses made a greater number of map delineations seem desirable, and, in the 1951-70, era surveys included over 100 units on an average with the more rolling, eroded counties having the most. In the 70's, 15 surveys have one-third less units per county indicating a trend toward more careful definition of each soil unit before it is accepted for final inclusion on a survey. This trend which started in the early 60's took so long to be noticeable due to publication delays. From the users standpoint this reduction of units is a great improvement. Every unit which must be studied and differentiated from others is an impediment toward understanding unless the unit is clearly different from its neighbors!

Due to pressure to complete Indiana's soil mapping with standard surveys in the present format by 1984 there will be a great push to speed up publication and many innovations will be tried. Also there will be a great need for educational programs to make the public aware of availability, use and value of each report as it is issued. To achieve maximum value this will need a real effort on the part of several agencies and efforts of the past will have to be developed and used much more widely.

The links developed through the years between soil scientists and other disciplines will need to be exploited more fully to bring soil knowledge and management experiences to all potential audiences! Today the main audiences include farmers and farm managers, foresters and wildlife managers, sanitarians and plan commissions, builders, developers, potential homeowners and real estate dealers, rural appraisers and assessors, scientists, architects and engineers.

Other specific user groups will require technical assistance to fully utilize soil surveys. A current need is for using surveys for land evaluation to aid assessors. Other needs will arise in the future though many are completely unforeseeable now. A good soil survey can be used to answer questions that were not even asked when the survey was made.

The challenge is there to increase the usefulness of the soil survey program and its maps and reports. They have served fully and well in the 73 years since the first one appeared in Indiana. They can be even more effective by the time the last ones are completed in the present

format sometime after 1984. How well they serve future needs will depend on the innovations made by this and the next generation of soil scientists and the workers with whom they have already established working relations or will do so in the years immediately ahead.

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ZOOLOGY

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was elected Chairman for 1976

ABSTRACTS

The Rediscovery of an Unusual Hydroid, *Keratosum complexum*. SEARS CROWELL, Department of Zoology, Indiana University, Bloomington, Indiana 47401.—In 1909 Hargitt described a hydroid from preserved specimens collected at Crab Ledge a few miles east from Chatham, Mass. Subsequently it has not been reported until we obtained a specimen in August, 1975 from the same location. The "thing" (Hargitt's expression) looks and feels like a sponge. Our specimen, completely covering the upper surface of a rock about 10 cm in diameter, consists of a basal mat of entwined stolons about 1 mm thick from which arise more than 100 slightly branching stems, 2-3 mm thick and up to 15 cm tall. The stems have a core of many parallel hydrocauli and a cortex of hydrothecae and nematothecae. Neither Hargitt's specimens, nor ours at the time of collection, had hydranths or gonangia. After a few weeks, some of the stems, kept at 5°C in the laboratory, developed good hydranths, which, however, failed to emerge from the hydrothecae. Also many thin stolons grew out from both the basal mat and the tips of the stems. Along the sides of the stems similar outgrowths appeared which had nematocysts in their tips and which can be regarded as simple nematophores. Hydrothecae are 0.18-0.24 mm wide, extend as much as 0.7 mm beyond the surface of the stem, and have an operculum of 12 triangular plates. Hydranths have 12 filiform tentacles. No gonosomal components have been found. The structure of the base, the stem, and the hydranths corresponds with these structures in *Clathrozoön wilsoni* of the thecate family Clathrozonidae. Although *Clathrozoön* and a second species *Pseudoclathrozoön cryptolarioides* are more branching than *Keratosum*, it seems to belong with them in the Clathrozonidae.

An Analysis of Some Techniques for Collecting Ectoparasites from Small Birds. GARY L. TIEBEN, Department of Biological Sciences, Indiana State University, Terre Haute, Indiana 47809.—Visual inspection, soap and water washing, and a potassium hydroxide dissolving technique were compared on each of twenty five House Sparrows (*Passer domesticus*). Numbers and types of parasites were noted for each technique. Washing produced significantly more mallophagans, primarily *Brueelia subtilis*; and feather mites, primarily *Protophyllodes truncatus*. Dissolving produced significantly more shaft mites, primarily *Syringophilodius minor*.

Mammals in the Indiana State University Vertebrate Collections. D. DAVID PASCAL, JR., GWILYM S. JONES, JOHN O. WHITAKER, JR., Indiana State University.—The research collection of mammals in the Indiana State University Vertebrate Collections presently contains nearly 6100 specimens representing 122 genera and 240 species. The collection is primarily from the United States and Canada, but representative species are present from 14 other countries.

Chromotropism in *Mermis nigrescens* Duj. MELVIN W. DENNER, Department of Life Sciences, Indiana State University Evansville in Evansville, Indiana 47712.—Cobb described a type of chromotropism associated with the egg laying of *M. subnigrescens* Cobb. According to his studies, release of eggs is due to the accumulation of the pigment haemoglobin in the anterior end and, to a lesser degree, throughout the body of the female. The presence of this pigment, in sunlight, is thought to provide the stimulus for egg laying as shown by Cobb and later confirmed by Christie. However, Ellenby and Smith, working on the haemoglobin pigmentation in *M. subnigrescens*, suggests that the distribution of pigment is more closely associated with respiratory functions and is particularly related to oxygen supply. They concluded that the concentration of pigment is not delimited enough to function in chromotropism.

In the present study, female *M. nigrescens* were collected during the early morning hours following an evening rain. The vegetation with the worms were taken back to the laboratory and examined for eggs, which were found in abundance on the vegetation. Several of these gravid females were placed on individual pieces of vertically placed moist filter paper in separately covered containers overnight in a dark room at room temperature. In another experiment, several lab-reared gravid females were removed from the soil in the absence of light and placed in similar containers overnight under the same conditions. When these pieces of filter paper were examined the next day, from 500-1500 eggs per female were present on the filter paper from each of the two groups. This seems to indicate that oviposition may occur in the absence of sunlight and that the presence of haemoglobin may not act as a chromatropic stimulus for egg laying.

The present study tends to indicate that although sunlight is not necessary for egg laying, it may influence it to some extent. This was evidenced by the somewhat greater number of eggs laid in the presence of sunlight than in darkness.

Host sex preferences of the nematode *Mermis nigrescens* Duj. MELVIN W. DENNER, Department of Life Sciences, Indiana State University, Evansville in Evansville, Indiana 47712.—Published reports on host sex preferences of mermithids, parasites of members of the order Orthoptera, shows considerable variability. Glaser and Wilcox found mermithid parasites in about 45% of female grasshoppers but only about 9% of the males. Christie found that 10.7% of male acrididae and 10.2% of the females were infected with *Agamermis decaudata* Christie. In the family Tettigoniidae, he found 14.6% of the females and 19.6% of the males parasitized with *A. decaudata*.

In the present study, 3,454 male and 3,418 female orthopterans were collected. Three subfamilies, Cyrthacanthacridinae, Oedipodinae, and Conocephalinae were the principal hosts collected in this study.

Field collections of grasshoppers were sacrificed, dissected with microdissection equipment and each was examined under a binocular stereomicroscope.

Results showed that 547 or 15.8% of the male grasshoppers harbored one or more mermithids and 602 or 17.6% of the females were parasitized. These results tend to support the work of Christie and seems to indicate that mermithids do not exhibit a strong host sex preference.

A Directional Photocell Technique to Monitor Activity of Volant Vertebrates. JEFFREY L. FISHER, Life Science Department, Indiana State University, Terre Haute, Indiana 47809.—A photoelectric cell system was devised to detect directional nocturnal movement of flying bats at the roost site in the fall of 1974. A light beam reflected across parallel mirrors focused upon a pair of photoelectric cells forming a detection grid across the plane of the roost exit. Bats *Eptesicus fuscus*, and birds, *Passer domesticus* interrupted the light beam and this event and the direction of movement was recorded. The light used had no detectable effect on either species. Direct observation of movements agreed well with apparatus counts.

Bovine Laterality: Resting Behavior. JACK L. ALBRIGHT, DOUGLAS H. YUNGBLUT, CLIVE W. ARAVE and JAMES C. WILSON, Department of Animal Sciences, Purdue University, West Lafayette, Indiana 47907.—Laterality of function in animals unlike right or left handedness in humans is of comparatively recent origin. Bovine laterality can be expressed in several ways: hooking tendencies in the bull ring; movements to the right or left in an open field maze; movement onto rotary milking parlors which rotate right or left; and resting behavior—lying on either their left or right side.

Dairy cows were observed during three 8.5 hour watches between 6:00 P.M.-2:30 A.M. during winter-spring confinement conditions. Cows were confined to loose housing with free stalls (individual 4 feet x 7 feet rectangles). Significance values were tested (chi square) against an expected mean of 50% lying on their left side. With level stall surfaces cows laid on their left side 53% (1854 observations $P < .10$) of the time. This is an agreement with recent work that cows tend to lie more on their left sides (52-56% of the time).

Jackson conducted two studies in Great Britain on the lying position of cattle. The first involved 340 observations of cattle of which 58.5% were lying on their left side while the second involved 493 animals of which 61% were lying on their left side. Wagnon and Rollins calculated the statistical significance of laterality in Jackson's studies to be $P < .001$.

A total of 3179 observations were made on six stall surfaces which sloped 1.5-2%. Cows laid with their dorsal side (backbone) uphill 55% ($P < .20$), 58,65,68,86 and 88% (all $P < .01$) for an average of 71%.

The first four values were for a clay base and the last two (86 and 88%) were for concrete-filled stalls. This finding could have immediate practical implications in the design of free stall barns. A slight slope of uniform direction would encourage cows to lie with their backs in the same direction. Therefore they would fit the stalls better and the incidence of teat injury caused by a cow stepping on another cow's udder might be reduced. In the long-run, encouraging cows to lie in a particular direction should be checked to assess the incidence of mastitis and digestive disturbances such as displaced abomasums.

Furthermore, ruminants sleep very little and one probable reason is that they eructate almost continuously. Also, for the rumen to remain comfortable and functioning normally the cow must remain in a fairly upright position. Hence resting on the left side on a surface slightly uphill is probably the most advantageous position.

Aminogluthethimide Kinetics in Fetal and Neonatal Rats (*Rattus norvegicus*). WILLIAM J. BRETT and VICKY M. WELLS, Department of Life Sciences, Indiana State University, Terre Haute, Indiana 47809. —Tritiated (^3H) aminogluthethimide (AG) was injected intraperitoneally into pregnant and post partum female rats in doses of 100 mg AG with a specific activity of 25 uCi/kg body weight. Cesarean deliveries were performed at 1, 3, and 5 days from injection. Pups were removed at 1, 3, and 5 days after injection from females which received one injection and at 1, 2, and 3 days from females which received three injections. Samples of placenta and amniotic fluid (fetus), milk and urine (pup), and blood, brain, liver and muscle (fetus and pup) were digested, dissolved in scintillation fluid and analyzed in a scintillation counter. All fetal tissues showed a significant uptake of AG with a relatively long depletion time. AG appears to be selectively absorbed by mammary tissue and secreted in the milk.

Coelomic Brood Protection of the Sea Cucumber, *Synaptula hydriformis*. SUSAN B. YANOS, DePauw University, Greencastle, Indiana, JOHN M. LAWRENCE, University of South Florida, Tampa, Florida. —*Synaptula hydriformis* broods the developing young within the coelomic cavity. Adult *S. hydriformis* were found to be hyperosmotic. Using tentacular movements as a measure of well-being, embryos removed from adults and directly exposed to reduced salinities had fewer tentacular movements than embryos from adults exposed to the same salinities. The adult coelomic fluid retards and reduces the effect of reduced salinities upon the embryos.

Preliminary Observations of the Nocturnal Activity of Insectivorous Bats and Their Prey in Wayne County, Indiana. ANDREAS R. RICHTER, GERTRUDE L. WARD, and JAMES B. COPE, Earlham College, Department of Biology, Richmond, Indiana 47374. —Food preferences and nocturnal activity patterns of insectivorous bats are in early stages of investigation. Little is known about nocturnal insect activity patterns, and few comparative studies exist. This study reports the activity of both bats and insects on the night of 30-31 June 1973, over Nolands Fork River, near Webster, Wayne County, Indiana. Bat activity was highest

during the first hour after sunset, lowest between midnight and 0400 hr., and then had a secondary peak just before sunrise. Insect activity was highest after sunset, and from 2100 hr. until sunrise decreased in a regular fashion without a secondary peak.

Bat Species Diversity Patterns in East Central Indiana. RICHARD S. MILLS, Aullwood Audubon Center, Dayton, Ohio 45414; GARY W. BARRETT, Department of Zoology, Miami University, Oxford, Ohio 45056; and JAMES B. COPE, Department of Biology, Earlham College, Richmond, Indiana 47374.—Bats were mist-netted weekly from 6 July through 5 October 1972 over Noland's Ford River in Wayne County Indiana. Seven species comprising 87 individuals (24 male, 63 female) were

captured and banded during this period. Information ($H' = -\sum_{i=1}^S p_i \log_e p_i$),

richness ($D = S - 1/\log_e N$), evenness ($e = H'/\log_e S$), and equitability ($e = S/S'$) species diversity values were found to be 1.42, 0.89, 0.73, and 0.86, respectively. These data indicate that this taxon lacks community richness. Species were found to be apportioned according to MacArthur's broken-stick model for contiguous, non-overlapping niches. The high equitability value suggests resource limitation; food is postulated to be the resource in short supply.

The Effects of Prostaglandin E_2 on Adrenal Regeneration Hypertension. PAULSON, D. J. and W. J. EVERSOLE, Indiana State University, Terre Haute, Indiana.—The effect of prostaglandin E_2 (PGE_2) on Adrenal Regeneration Hypertension was investigated in Charles River female rats. Four groups of 23 ± 1 day-old rats underwent right adrenalectomy and left adrenal enucleation. The rats were maintained on tap water for 18 hours and then given 1% saline drinking solution. Each group received daily subcutaneous injections of 0.9% saline or PGE_2 (20, 40, or 80 μ g per day). Blood pressures were determined by a tail and cuff method at 3, 5, and 7 weeks following surgery. The rats were sacrificed at 7 weeks and the kidney, heart, thymus, and adrenal were removed and weighed. Injections of 20 and 40 μ g PGE_2 per day produced a progressive reduction in blood pressures, mean kidney and heart weight, but the differences from control values were not statistically significant. Administration of 80 μ g PGE_2 per day caused a significant fall in blood pressure at 5 ($P < .01$) and 7 ($P < .05$) weeks. The mean heart weight of this group was also significantly less than the control ($P < .05$) and the mean kidney weight was reduced but not significantly so. Thymus and adrenal weights showed no significant change. This study suggested that a deficiency of renal PGE_2 may be involved in the etiology of Adrenal Regeneration Hypertension. (Aided by a grant from the Eagles' Max Baer Heart Fund).

Catalysis of an Allosterically Inhibiting Nucleotide with a Synthetic Estrogen and a Subsequent Alteration in Ovarian Metabolism. GREG CAPLINGER,* Dept. of Zoology, Anderson College, Anderson, Indiana. (Intr. by Marie Mayo).—The ovarian synthesis of proteins may be subject to amino acid alterations as a result of the treatment with synthetic estrogens. Wistar white adult female rats were given intramuscular

injections of a synthetic estrogen compound known as Mestranol (17-ethynylestradiol 3-methyl ether) which was followed by the isolation of two distinct cell free ovarian proteins in both the experimental and the control groups. When looking at the biosynthesis of estrogen one sees that NAD is needed in the conversion of cholesterol to Δ^5 -pregnenolone. Also it has been noted that NAD will allosterically inhibit LDH and thus decrease the LDH content. In the ovarian synthesis of estrogen we found a very unique interrelationship in the metabolic scheme. First of all it was recognized that Mestranol injected in small quantities acted to catalyze the reaction involving NAD and thus an allosteric inhibition and a lower level of LDH was measured. Also the elevated level and catalysis of NAD resulted in the addition of amino acid residues to the two isolated ovarian proteins. With a subsequent use of a high quantity of Mestranol the NAD level was decreased, thus alleviating the allosteric inhibition of LDH. This decreased level of NAD resulted in the deletion of amino acid residues from the two isolated ovarian proteins. From this unique metabolic scheme there has developed the uncovering of a two way recognition mechanism. Cholesterol levels are not altered by the Mestranol alone but cholesterol recognizes the physiological estrogen in the normal negative feedback pattern and the levels of Mestranol are recognized by NAD. In conclusion one can see how the injections of a synthetic estrogen have induced changes in the amino acid content without a subsequent change in the estrogen level. With a prolonged alteration in the amino acid content there will no doubt be an induced nucleotide alteration which will change the ovarian biosynthetic pattern.

The Effects of *in vitro* Culture on *Tritrichomonas suis* in Chick Chorio-allantoic fluid

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Abstract

Culturing of *Tritrichomonas suis* in chick chorio-allantoic fluid resulted in lower numbers and smaller individuals than when cultured in the commercial laboratory medium, C.P.L.M. A primary cause for this difference may be based on carbohydrate utilization.

Introduction

Culturing of protozoa in the laboratory is an essential part of many types of protozoological research done today. Among the protozoa, trichomonads in culture have been used widely throughout the world. Following the initial report by Nelson (10) of culturing *Trichomonas foetus* beneath the chorio-allantoic (C.A.) membrane of the developing chick embryo, a number of workers including Hogue (4), Trussell and Plass (15), and Florent (3), have used embryonic fluids *in situ* for culturing various trichomonads. Literature concerning the use of extra-embryonic fluids of developing chicken embryos for the culture of trichomonads was reviewed by Marr (8). Very little information is available concerning the effectiveness of this substrate for trichomonad culture.

This investigation was designed to determine the population growth characteristics and to determine the morphological characteristics of *Tritrichomonas suis* under *in vitro* C.A. fluid culture.

Materials and Methods

A long-term C.A. fluid *in vitro* growth experiment was initiated using 8 cultures incubated at 30°C and 7 tubes at 36°C. The population of protozoa was determined every 12 hours with the aid of a hemocytometer until the cultures died out. Three sets of slides from each temperature were prepared. These sets consisted of smear preparations of the inoculum from C.P.L.M. medium of Johnson and Trussell (14) and smears made after 4 and 6 days of C.A. fluid culturing.

Stained specimens were prepared for morphological studies using Heidenhain's iron hematoxylin following fixation with Schaudinn's fluid and with a modified protein silver stain of Bodian (1) and Moskowitz (9) following Bouin's fixation. Hematoxylin was used primarily to show gross body dimensions and nuclear detail while protein silver was used to demonstrate the argyrophilic mastigont structures such as flagella, undulating membrane, axostyle, and parabasal body.

Chorio-allantoic fluid for this experiment was prepared by using the following procedure. The C.A. fluid of eggs incubated 13 days was drawn by mouth aspiration into a length of 3/16-inch rubber tubing and pooled in a rubber stoppered Erlenmeyer flask. The tube was equipped

with a 2-inch, 19-gauge needle and a cotton stoppered mouth piece. Sterilization of the fluid was accomplished by passing it through a 0.1 μ Seitz filter under vacuum into a sterile Erlenmeyer flask. This sterile C.A. fluid was dispensed with a 5-ml Leur syringe equipped with a 3.5-inch, 15-gauge needle in 3.9 ml amounts into screw cap test tubes (16 x 150 mm) for culture. The inoculum for each tube consisted of 1.5×10^5 trichomonads suspended in 0.1 ml of C.P.L.M. medium.

Results

Peak populations of 3.94×10^6 and 4.08×10^6 organisms were reached after 4 days of C.P.L.M. culturing at 30°C and 36°C. Measurable populations were recorded from all 10 control culture tubes for 8 and 7 days at the respective temperatures (Figure 1). Minimum generation

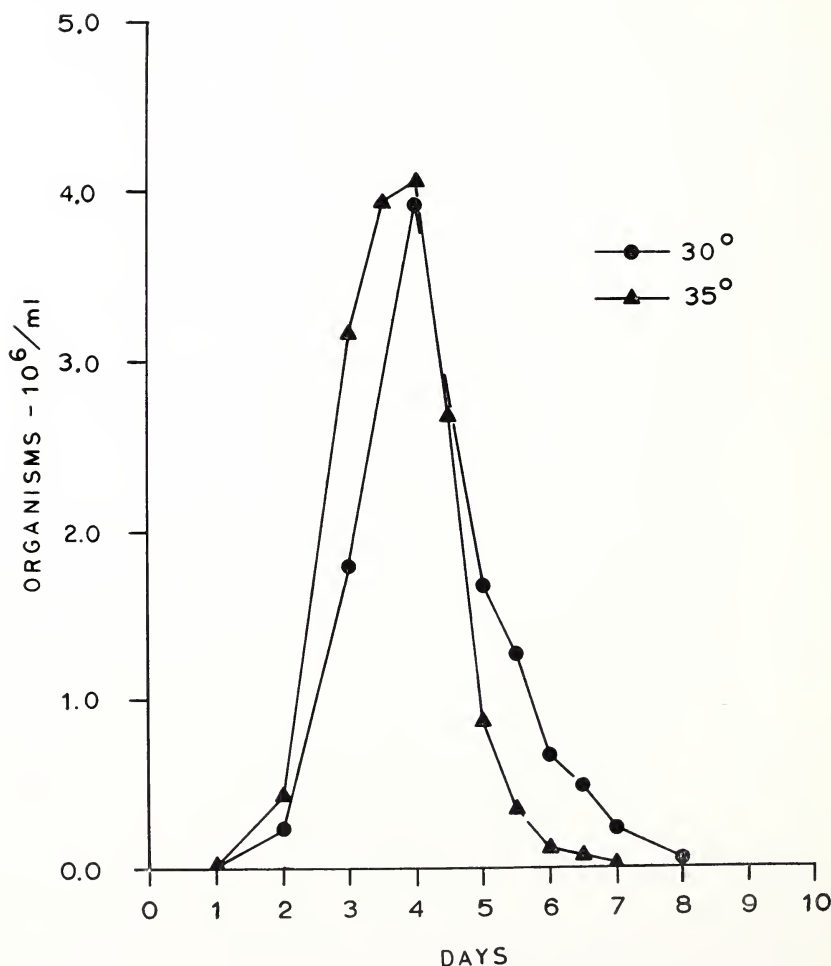


FIGURE 1. Population growth curves of *T. suis* in C.P.L.M. medium.

times of 6.6 and 6.1 hours were calculated for the control temperatures. Following the population peaks a logarithmic decrease occurred at both temperatures.

The maximum number of trichomonads reached after 6 days of 30°C C.A. fluid *in vitro* culturing was approximately 900,000 per ml, while a population of 1.15×10^6 per ml was reached in 4 days in those cultures incubated at 36°C (Figure 2). Those cultures incubated at 30°C reached a second peak which approached 900,000 organisms per ml in 8.5 days. The cultures incubated at 36°C also gave a slight indication of a second population peak after 5.5 days with 4 of the 7 cultures used exhibiting an increase; however, the overall population mean of the 7 cultures was lower than the previous reading. The duration of time in which measurable populations were found in each tube was 13 days for the 30°C cultures and 7 days for the 36°C cultures.

The generation time as determined from the straight line curve of the semilog plot of the populations during the logarithmic phase of growth was 26.2 hours in the 30°C cultures and 16.1 hours in the 36°C cultures. From the peak population, the rate and nature of decrease of the 36°C cultures followed very closely a logarithmic decrease as compared to the more gradual decline of the 30°C cultures.

Those organisms cultured at 30°C were longer and wider ($10.74 \pm 0.16 \mu$ by $5.06 \pm 0.12 \mu$) than those cultured at 36°C ($9.46 \pm 0.16 \mu$ by $4.67 \pm 0.12 \mu$) after 4 days incubation in C.A. fluid. After 6 days of culturing the same relationship was seen in regard to length, $9.83 \pm 0.16 \mu$ compared to $9.13 \pm 0.16 \mu$; however, the widths were

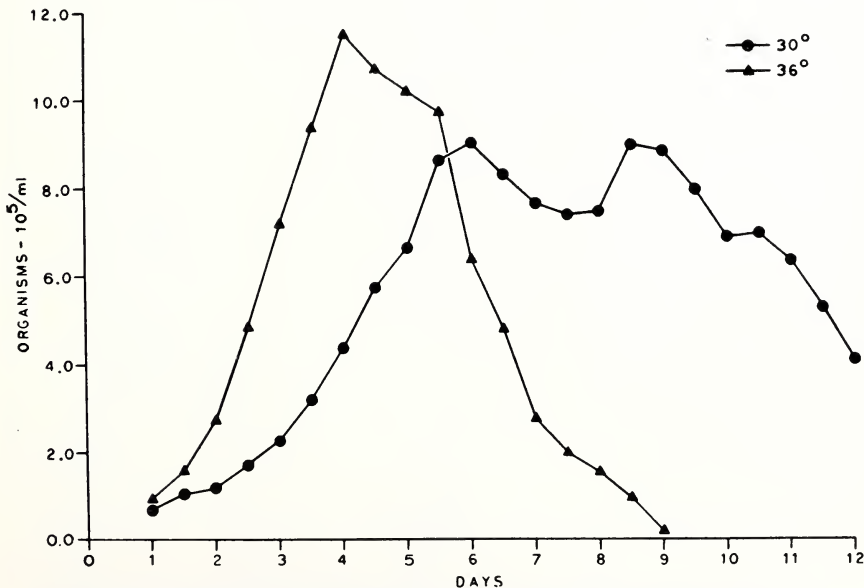


FIGURE 2. Population growth curves of *T. suis* in chorio-allantoic fluid *in vitro*.

essentially equal, being $4.81 \pm 0.12 \mu$ and $4.80 \pm 0.12 \mu$ respectively. In both cases there were decreases in length of the organisms compared to the length of $12.55 \pm 0.16 \mu$ of the organisms of the inoculum. Conversely, the widths of those organisms cultured at 30°C ($5.06 \pm 0.12 \mu$) and 36°C ($4.67 \pm 0.12 \mu$) were larger than the width ($4.31 \pm 0.10 \mu$) of the organisms of the inoculum (Tables 1 and 2).

Nuclear measurements taken from organisms of the experimental culture at 30°C ($3.17 \pm 0.10 \mu$ by $1.94 \pm 0.07 \mu$) and 36°C ($2.59 \pm 0.10 \mu$ by $1.87 \pm 0.07 \mu$) after 4 days culturing were slightly smaller as were those measurements taken after 6 days; 30°C ($2.88 \pm 0.10 \mu$ by $1.85 \pm 0.07 \mu$) and 36°C ($2.76 \pm 0.10 \mu$ by $1.99 \pm 0.07 \mu$) than those of C.P.L.M. cultured organisms of the inoculum type (Tables 1 and 2).

TABLE 1. *Measurements^a of T. suis cultured in chorio-allantoic fluid in vitro at 30 C.*

Characteristic	0 days	4 days <i>in vitro</i>	6 days <i>in vitro</i>
Length -----	12.55 ± 0.16 (55)	10.74 ± 0.16 (40)	9.83 ± 0.16 (40)
Width -----	4.31 ± 0.10 (55)	5.06 ± 0.12 (40)	4.81 ± 0.12 (40)
Nuclear length -----	3.28 ± 0.06 (69)	3.17 ± 0.10 (20)	2.88 ± 0.10 (20)
Nuclear width -----	2.14 ± 0.04 (69)	1.94 ± 0.07 (20)	1.85 ± 0.07 (20)
Parabasal body length -----	3.71 ± 0.15 (25)	3.36 ± 0.27 (1)	2.78 ± 0.13 (20)
Parabasal body width -----	0.52 ± 0.02 (25)	0.48 ± 0.03 (1)	0.48 ± 0.01 (20)
Axostylar projection -----	1.94 ± 0.17 (25)	2.40 ± 0.18 (19)	2.17 ± 0.18 (19)

^a Mean (μ) $\pm$ standard error; observations in ().

TABLE 2. *Measurements^a of T. suis cultured in chorio-allantoic fluid in vitro at 36 C.*

Characteristic	0 days	4 days <i>in vitro</i>	6 days <i>in vitro</i>
Length -----	12.55 ± 0.16 (55)	9.46 ± 0.16 (40)	9.13 ± 0.16 (40)
Width -----	4.31 ± 0.10 (55)	4.67 ± 0.12 (40)	4.80 ± 0.12 (40)
Nuclear length -----	3.28 ± 0.06 (69)	2.59 ± 0.10 (20)	2.76 ± 0.10 (20)
Nuclear width -----	2.14 ± 0.04 (69)	1.87 ± 0.07 (20)	1.99 ± 0.07 (20)
Parabasal body length -----	3.71 ± 0.15 (25)	2.88 ± 0.60 (5)	2.57 ± 0.14 (17)
Parabasal body width -----	0.52 ± 0.02 (25)	0.48 ± 0.06 (5)	0.51 ± 0.01 (17)
Axostylar projection -----	1.94 ± 0.17 (25)	1.24 ± 0.18 (19)	2.13 ± 0.21 (14)

^a Mean (μ) $\pm$ standard error; observations in ().

The parabasal body was progressively shortened at both experimental temperatures (Tables 1 and 2).

In slides from the 36°C culture, the trunk of the axostyle had assumed in about 25% of the population a sigmoid configuration (Plate I-1, 2, 3) in contrast to the rather straight-to-slightly-curved trunk normally seen (Plate I- 4, 5, 6). This configuration might have been caused by excessive shrinkage of the cell causing this axial rod

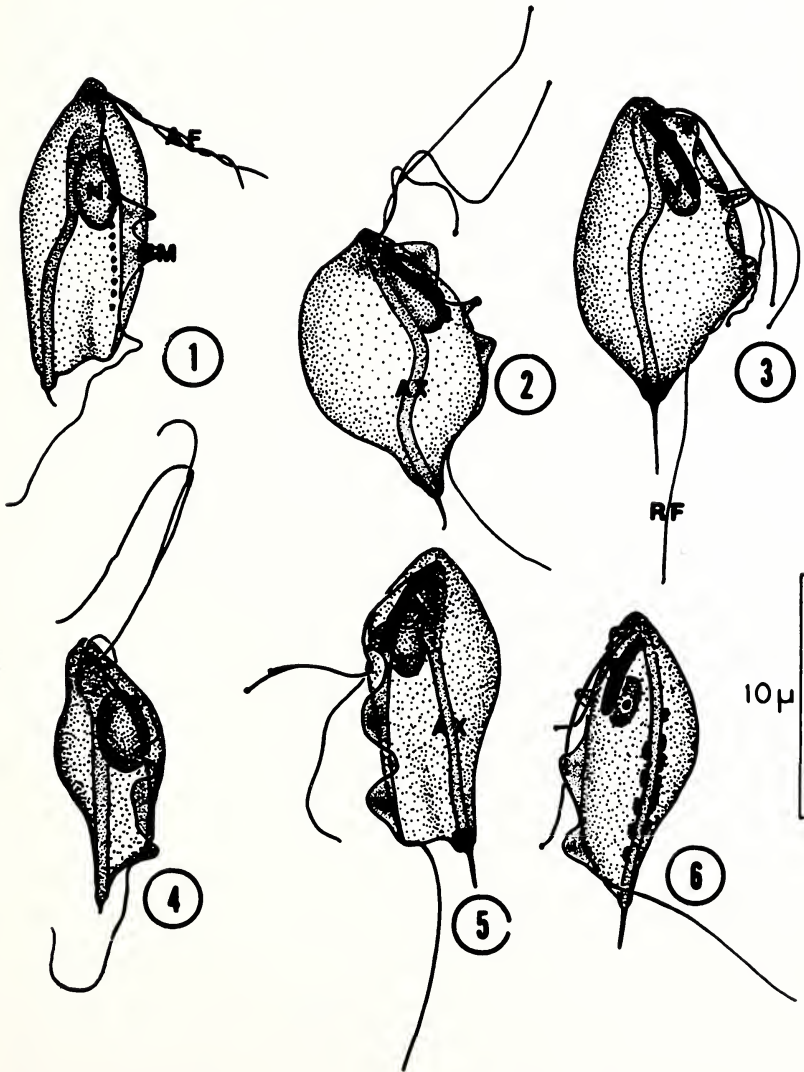


PLATE I. 1, 2, 3, 4, 5, 6. *Tritrichomonas suis*, nucleus (N), undulating membrane (UM), parabasal body (P), anterior flagellum (AF), recurrent flagellum (RF), axostyle (AX).

to partially fold on itself; however, measurements taken at this point in the experiment did not reveal a noticeable difference in size of these organisms from those that had a more conventional appearing axostyle.

No apparent variability in the anterior or recurrent flagella or undulating membrane was noted between organisms cultured in C.A. fluid and those cultured in C.P.L.M. medium.

Discussion and Conclusions

These data indicate a pattern which has not been seen in trichomonad studies previous to this time. The second peak in population established during the culture cycle can be compared to the diauxic pattern of growth described by Thimann (13) in bacterial populations and by Daly (2) in a strain "X" of *T. gallinae*. However, the lag phase and subsequent reacceleration of growth here does not occur midway during the log phase of the cycle. The normal pattern of diauxic growth is based on the preferential metabolism of available carbohydrates in the medium in which all of the preferred energy source is utilized before the second is attacked. According to Romanoff (12), approximately 90% of the carbohydrate of chicken allantoic fluid is glucose. This large amount of one sugar might explain why the second increase occurred during the stationary phase of the cycle rather than the log phase.

This carbohydrate difference could also have been responsible for the lower peak population attained as compared to C.P.L.M. cultured controls. The major carbohydrate of C.P.L.M. medium is maltose although there is also an undefined amount of carbohydrate present due to the addition of liver extract to the medium.

The comparison of various laboratory media with these two sugars has been conducted using several species of trichomonads and in each case the maltose supplemented media supported better protozoan populations (14, 11, 7, 5).

The general decrease in body dimensions and organelle size in C.A. fluid cultured *T. suis* is also probably due to this carbohydrate difference. Read (11) and Daly (2) also noted that laboratory media supplemented with maltose supported trichomonads that were larger and heavier than those cultured in glucose supplemented media.

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First report of *Psorergates simplex* Tyrrell, 1883 (Acari: Psorergatidae)
from wild House Mouse, *Mus musculus*, in the United States

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Abstract

Psorergates simplex Tyrrell, 1883, is reported from wild house mice, *Mus musculus*, in the United States for the first time. Two female mice from Pike County, Indiana, had 67 skin pouches containing numerous mites of all developmental stages and eggs. Pouches averaged 0.8 by 0.6 mm in size with one 0.2 mm opening. The ratio of male to female mites was 1 to 10. Female mites from ear scabs of one female mouse were slightly larger than those in the pouches.

Introduction

There are no records of *Psorergates simplex* Tyrrell, 1883 from wild house mice, *Mus musculus*, in the United States. Only two other reports of *P. simplex* in North America exist, Tyrrell's species description (12) and Flynn and Jaroslows' discussion of its nidification in the skin of laboratory mice (8). Unfortunately, the type specimen is unknown and Tyrrell's original description and figures are not adequate for species determinations. Taxonomic problems associated with *P. simplex* are discussed by Fain, et al. (7).

The purpose of this paper is to present information on *Psorergates simplex* found in skin pouches on wild house mice, *Mus musculus*, in Indiana. Pathogenic roles of psorergatid mites in the production of dermal lesions in vertebrates has long been known but most studies have been done in Europe.

Materials and Methods

Five house mice, *Mus musculus*, were snap-trapped in Pike County, Indiana, in June, 1974. Numerous skin pouches were observed on two females during routine examination for ectoparasites. Sebaceous material forced from pouches with micro-forceps was preserved in 70 percent ethonol, cleared and stained in a mixture of Nesbitt's fluid and acid fuchsin and mounted on microscope slides in Hoyer's solution. Microscopic analysis revealed numerous psorergatid mites in all stages from eggs to adults mixed with the sebaceous material. The mice were preserved in 10 percent formalin and then transferred to 70 percent ethonol for permanent storage.

All skin pouches of both female mice and 72 percent of the pouch openings were measured. The sebaceous material from all pouches was removed, cleared and stained. The contents of only 18 skin pouches were suitable for mounting, i.e., not completely dissociated. The total number of males, females, nymphs, larvae and embryonated and non-embryonated eggs was determined for each of the 18 pouches. The average total length of 20 specimens of each mite stage (except nymphs) and the average diameter of 20 of both kinds of eggs was

determined. Ear scabs and ear scrapings of one female were cleared, stained and mounted. A series of 20 female mites from that sample was measured for total length.

Results and Discussion

Out of 5 (2 male, 3 female) adult house mice, *Mus musculus*, 2 females possessed many skin pouches containing numerous mites, *Psorergates simplex*. One of the two females had thick scabs on its ears under which additional psorergatid mites were found. One male mouse had thin scabs on an ear and a pouch-like lump behind one ear but no mites were found in association with either the scabs or the lump. The presence of *Psorergates simplex* under scabs on the ear pinna and in skin pouches on the same individual is of interest. Tyrrell (12) described *P. simplex* from mice which harbored the parasite in "a crusty scab on the lower part of the back of the ear, extending round its outer edge and into the interior of the conch." No mention was made of skin pouches. On the other hand Flynn and Jaroslow (8) reported *P. simplex* occurring only in skin pouches of laboratory mice in Illinois. In two different areas in Belgium, Fain, et al. (7) found a species of psorergatid mite on *Mus musculus* in lesions on the ear (at Hamert) and in nodules on the body (at Nijmegen). Three species of psorergatid mites, *Psorergates cinereus*, *P. canadensis* and *P. watsoni* have been found in association with ear scabs of *Sorex cinereus*, *Microtus pennsylvanicus* and *Peromyscus maniculatus*, respectively, in Canada (9). *Psorergates glaucomys* was reported in a nodule by the ear of *Glaucomys volans* from Georgia (1). From the present study it is apparent *P. simplex* can occupy two different microhabitats on the same host.

Skin pouches occurred mainly on the face around the eyes (Fig. 1), on the lower part of the legs and in the perianal region of both females. A few pouches were scattered on the dorsum and sides of the mice. Skin pouches caused by psorergatid mites may be found on any part



FIGURE 1. Photograph of female House Mouse, *Mus musculus*, with skin pouches (by eye) and scabs (on ear) induced by *Psorergates simplex*.

of the body but they are usually concentrated around the eyes (2, 8), on the less hairy portion of the leg (5) or all over the body (6).

The two female mice had a total of 67 skin pouches which averaged 0.8 mm (range 0.4-1.6) long, 0.6 mm (range 0.3-1.2) wide, with an average opening diameter of 0.2 mm (range 0.1-0.4). The 18 skin pouches used in determining the total numbers of mites and eggs (Table 1) averaged 1.0 mm (range 0.7-1.5) long, 0.7 mm (range 0.4-1.1) wide, with an average opening diameter of 0.2 mm (range 0.1-0.4). Flynn and Jaroslow (8) reported pouches as large as 2 mm in diameter. Beresford-Jones (4) found psorergatid mites in cysts 0.5 to 1 mm in diameter. All the skin pouches of *Psorergates simplex* had an opening as described by Flynn and Jaroslow (8). The opening is probably the old site of a hair if the typical pouch is initiated by the entrance of one or more parasites into a hair follicle as proposed by Neuman (11) and believed by Flynn and Jaroslow (8). Beresford-Jones (3) reported only some psorergatid cysts with openings.

TABLE 1. Average numbers of mites, *Psorergates simplex*, and eggs and average total lengths of the mites (except nymphs) and diameters of eggs in skin pouches on house mice, *Mus musculus*, in Indiana. Ranges are in parentheses.

	Average Total Length (μ)	Average No. per Pouch
Females (from ears) -----	127 (113-140)	-----
Females -----	115 (105-123)	31.2 (11-67)
Males -----	104 (88-110)	3.1 (0-10)
Nymphs ¹ -----	-----	13.1 (0-33)
Larvae -----	91 (75-113)	17.4 (3-56)
Embryonated eggs -----	78 (75-83)	16.6 (0-72)
Non-embryonated eggs -----	76 (75-78)	29.3 (1-112)

¹ Proto- and deutonymphs were not measured because it was difficult to tell them apart.

The average number of skin pouches on the two mice was 33.5. Beresford-Jones (4) found the usual number of psorergatid cysts was 1 to 8 although one mouse had 17 and another 22.

The average number of mites and eggs per pouch, average total lengths of mites and average diameters of eggs are given (Table 1). Female mites were most abundant and males least abundant. The ratio of males to females was 1 to 10. Beresford-Jones (4) reported 5 to 7 females to 1 male in his studies of psorergatid mites.

The female mites located under the ear scabs were slightly larger (Table 1) than those in pouches. It is possible that conditions under the scabs were not as confining as in skin pouches. The possibility of the mites on the ears being either a different species or subspecies than those in the pouches is being explored.

Only four other species of *Psorergates* are known from North America (9, 1). The latter authors and Lukoschus, et al. (10) list studies of psorergatid mites in Asia, Australia, Europe, Malaysia and South America. Fain, et al. (7) indicate it is preferable to consider *Psorerg-*

gates simplex a species distinct from psorergatid mites on *Mus musculus* in Europe until *P. simplex* can be redescribed from specimens from the type locality. The redescription is underway (F. S. Lukoschus, pers. comm.). Whitaker (13) examined 470 house mice in Vigo County, Indiana, for ectoparasites and found none with psorergatid pouches.

Ectoparasites found on the five house mice were *Androlaelaps fahrenheitsi* (1 individual found), *Myocoptes musculus* (20), *Myobia musculi* (1), *Radfordia affinis* (1) and two immature myobiid mites. Those four species have been found on *Mus musculus* before (14).

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Effect of Aminogluthethimide on Rabbit EKG and Blood Pressures

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Abstract

Aminogluthethimide (Elipten-Ciba, AG) administered IV 50 mg/kg BW to level three anesthetized New Zealand White rabbits, was found to produce parallel reductions in intraventricular and systemic pressures. Time of obtainment of maximum pressure decrease was influenced by rate of injection. Heart rate decreased in conjunction with the decrease in pressures. The absence of a reflexive increase in heart rate during the period of decreased pressures suggests a sympathetic-vagal mediated action by AG. An alternative hypothesis is suggested by AG's previously described role as an anticonvulsant: decreased muscular activity would also result in lowered blood pressures. No arrhythmia could be attributed to AG.

Introduction

Aminogluthethimide (alpha-(para-aminophenyl)-alpha-ethyl glutarimide, Elipten, AG) is a derivative of the nonbarbiturate hypnotic glutethimide and was introduced as an anticonvulsant in 1960. By 1966 the U.S. Food and Drug Administration had withdrawn it from the market following reports of unfavorable side effects during clinical usage: goitrous hypothyroidism (20), adrenal insufficiency (4,5) and congenital pseudo-hermaphroditism (8). AG was given Investigational New Drug status in 1966 by the F.D.A. to allow continued dispensation to epileptics who were dependent upon AG for remission of seizures and to allow experimental evaluation. Further studies have shown AG to be a competitive inhibitor of the mitochondrial desmolase enzyme system blocking steroidogenesis at the conversion of cholesterol at Δ -5-pregnenolone (4, 26).

Recently AG has been used in treatment of cancer of the breast (4, 6, 13) and prostate (22), in treatment of tumors of the adrenals (5, 24), in treatment of primary and secondary hyperaldosteronism (5, 10, 27), and to induce abortion (9).

AG has been shown to increase urinary sodium through a reduction in aldosterone secretion (3, 4, 5, 14). Fishman et al. (5) reported a marked sodium diuresis in patients on 0.75 to 2.0 g AG/day with no concomitant change in serum electrolyte concentrations. Camacho et al. (3) reported a decrease in serum sodium and chloride and an increase in serum potassium in patients on 0.75 to 1.0 g AG/day within three days. Pollock (19) found a decrease in serum sodium and an increase in serum potassium 30 minutes after an injection of 100 mg AG/kg BW in homeotherms but not in poikilotherms. Zimmerman (28) also reported similar serum electrolyte changes with elevated tissue sodium and depressed tissue potassium in the rat. Studies on adrenalectomized rats led Zimmerman to conclude that AG caused a shift of potassium from plasma to tissue and of sodium from tissue to plasma independent of any adrenal cortex mediated action.

Hayden and Brett (7) found that AG caused an increase in the potassium efflux of rabbit red blood cells without changing sodium influx. They concluded that AG enters the RBC and may occupy site(s) in or on the membrane and hypothesized that AG may change membrane permeability or sodium-potassium ATPase activity in the membrane.

The observation by Pollock (19) that an intracardial injection of AG produced cardiac arrest in ventricular diastole followed by resumption of activity at a faster rate with stronger force, suggested a pilot study on the effect of AG on the heart. AG was found to induce tachycardia in the turtle for approximately 24 minutes with reoccurrences of tachycardia of one minute every 20 minutes. The electrocardiogram evidenced a shortened T-P (rate determined) and P-R (pacemaker location or conduction rate determined) interval with no QRST changes. No cardiac arrest was observed but other pilot studies have reported that a topical application of AG on an arrhythmic turtle heart restored rhythmicity (Brett, Personal Communication).

This study was to determine AG's effect on heart action—electrical and contractile as measured by EKG and blood pressure.

Materials and Methods

Methoxyflurane (Penthane: Abbott Labs) was selected as the anesthetic because of its reported minimum effect on heart activity. Brown (2) and others have reported no EKG changes with Methoxyflurane. However, depression of myocardial contractility with Methoxyflurane has been reported by many investigators including Woods (1), Brown (2), and Redondo et al. (21) but is reported to be less than for Ethrane, Halothane and chloroform. Methoxyflurane does not sensitize the heart to epinephrine nor does it cause a release of catecholamines into the blood stream (16).

Induction of anesthesia was performed with diethyl ether in a closed chamber 15 minutes after subcutaneous injection of 0.05 mg/kg BW atropine (atropine methyl bromide) at the scruff of the neck to alleviate excessive salivation and mucus secretions due to ether irritation. Eye blink and muscular relaxation were used as indicators of level of anesthesia. Surgical anesthesia (level three) was maintained with Methoxyflurane administered through a tracheal cannula inserted below the larynx. Methoxyflurane vaporized by copper kettle technique was administered through non-rebreathing open circuit with pressure maintained by a Narco respirator (Narco Bio-Systems). Induction of Methoxyflurane was accomplished on a 2:1 inspiration-expiration ratio with maintenance on a 1:1 ratio. Inflation of the lungs with an average of 16 cm water pressure occurred 70 times a minute.

Systemic blood pressure was obtained by cannulation of the right femoral artery with Intramedic P50 polyethylene tubing inserted to the aorta. Left ventricular pressure was acquired by passing a cannula into the left ventricle via the right carotid through the semilunar valves. Intraventricular and systemic pressures determined by Satham P23Db transducers were recorded in conjunction with EKGs from needle elec-

trodes on a Gilson ICM-5 Polygraph at a paper speed of 25 mm/sec. After stabilization on Methoxyflurane, the vehicle was injected as a control and then 50 mg AG/kg BW was injected into the marginal ear vein and the parameters were monitored. AG was maintained in a solution of distilled water of pH 4 (HCl) at a concentration of 100 mg AG/ml. Elapsed time of injection was influenced by volume of AG solution and by rate of venous drainage.

Records were analyzed for changes in pressures, heart rate and arrhythmias. Data were subjected to statistical analyses utilizing regression analysis and Students' "t" test.

Results

Durations of the various intervals and waves of the EKGs were found to be within the normal ranges (12,15,25) for all rabbits observed. Injection of AG produced significant ($p>.01$) parallel reductions in intraventricular and systemic pressures (Table 1). The rate of injection influenced the time required for the pressure to reach maximum decrease. There is a general direct correlation between rate of injection and time to maximum decrease in pressure (Fig. 1). All AG

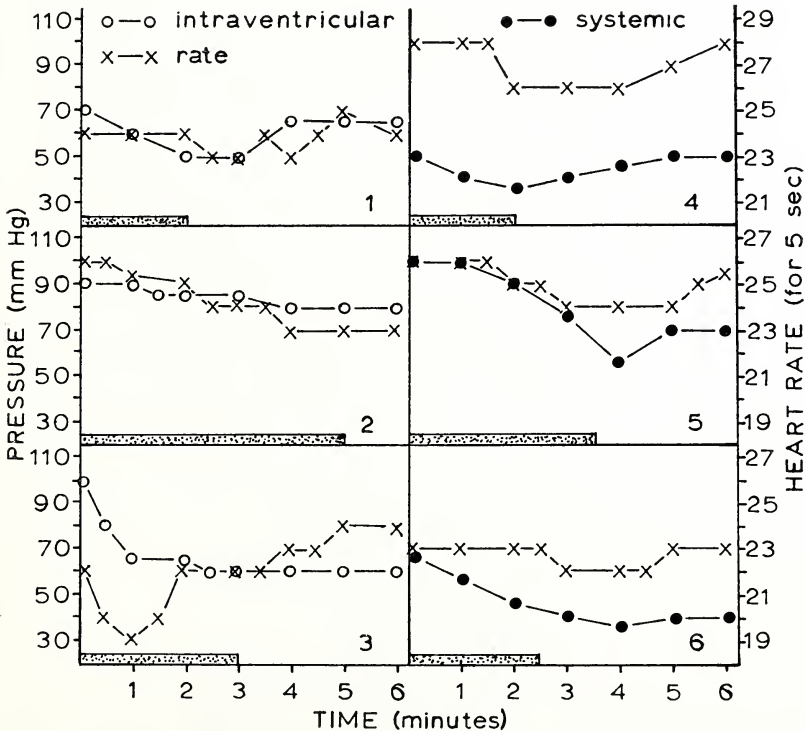
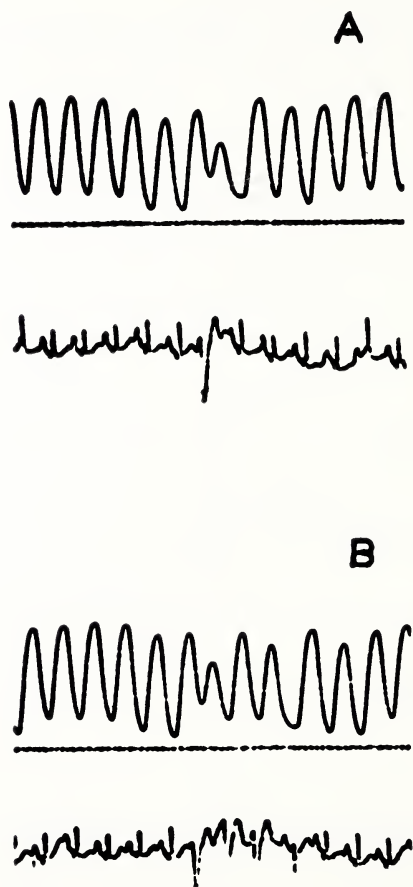


FIGURE 1. Heart rate and intraventricular pressures for rabbits 1, 2, and 3 and systemic pressures for rabbits 4, 5, and 6 are plotted as a function of time from start of AG injection. Duration of AG injection is expressed as a bar on the time axis.

injected rabbits showed a decrease in heart rate which lagged behind the decrease in intraventricular and systemic pressure (Fig. 1).

Both AG and control cannulated animals evidenced an arrhythmia in the form of premature ventricular beats; one rabbit also developed paroxysmal ventricular tachycardia (Fig. 2).



TIME (2.5 cm=1sec)

FIGURE 2. EKG (Lead II) strip A is an example of a premature ventricular systole in an anesthetized, cannulated animal. Tracing B shows a series of premature ventricular systoles—paroxysmal ventricular tachycardia. Premature beats are due to an enhanced pacemaker. Intraventricular pressure appears as the upper recording on both strips.

TABLE 1. *Intraventricular (I) and systemic (S) pressures for anesthetized, cannulated rabbits injected IV with 50 mg AG/kg BW.*

1	I	70/5	60/10	50/10	50/15	65/10	65/40	65/40
(2 min)	S	70/50	50/40	50/45	50/40	50/40	50/40	50/40
2	I	90/0	90/0	85/0	85/0	80/0	80/0	80/0
(5 min)	S	85/60	85/60	80/55	80/55	80/50	80/50	80/60
3	I	100/20	65/10	65/20	60/20	60/20	60/20	60/20
(3 min)	S	90/80	50/40	40/35	40/35	40/35	40/35	40/35
4	I							
(2 min)	S	50/40	40/30	35/30	40/35	45/40	50/35	50/40
5	I							
(3.5 min)	S	100/75	100/70	90/65	75/45	55/35	70/45	70/45
6	I							
(2.5 min)	S	65/45	55/40	45/40	40/35	35/30	40/35	40/35

Discussion

Blood pressure in the functioning organism is determined by blood volume, vascular resistance and cardiac output. In the present study, blood volume was considered to be a constant. Under constant vascular resistance, intraventricular pressure is an index of myocardial contractility. With changes in vascular resistance, intraventricular pressure loses its value as an index to contractility. A constant myocardial contractile level with a decrease in vascular resistance would be observed as a decrease in intraventricular and systemic pressure due to a decreased column of blood that the heart would be ejecting against. Lowered myocardial contractility with a constant vascular resistance also would be demonstrated as a decrease in intraventricular pressure. AG reduces both intraventricular and systemic pressures which could be due to a decrease in vascular resistance and/or myocardial contractility.

The effects of the anesthetic on the physiological parameters of the organism always present a problem when one is attempting to analyze the effects of a specific drug. Methoxyflurane was selected because of its minimal effect on heart action. Methoxyflurane produces its negative inotropic effect on heart muscle by blocking glycolysis prior to the phosphofructose kinase step and by some other mechanism (17, 18). Paradise and Ko (18) suggest a variety of action sites in the heart for Methoxyflurane. In the present study, Methoxyflurane's depressant action, evidenced by intraventricular recordings, was allowed to stabilize before injection of AG; therefore, the additional decrease in pressure upon AG injection indicates an AG or AG-Methoxyflurane mediated action.

AG appears to have a triform action on the cardiovascular system of the anesthetized rabbit. These actions may or may not be independent of one another—decreased intraventricular pressure, decreased systemic pressure and decreased heart rate. Two mechanisms may be proposed to explain these actions and the time factor involved in them. AG may affect the ionic stability of the cell or it may affect sympathetic and/or vagal tone.

Increases in K^+ efflux from rabbit RBCs has been shown to occur with AG. Hayden and Brett (7) have suggested that this may be due

to AG's effect on ATPase inhibition or to a change in membrane permeability since AG does not increase Na^+ influx. The decrease in muscular activity observed upon injection of AG could result from K^+ efflux from muscular cells. With a decrease in muscular activity, vasodilation would result from relaxation of the vascular bed. Blood with an increased K^+ content would pool in the tissues, increasing dilation. Intraventricular pressure would decrease due to both a reduction in venous return to the heart and to a proposed loss in contractility.

Sympathetic control influences muscle relaxation, pacemaker activity, speed of conduction through the AV node, and cellular metabolism. Catecholamines mediate sympathetic control with norepinephrine having the major influence in the heart. A decrease in sympathetic tone would produce a decrease in intraventricular pressure through several mechanisms: lengthening of time-to-peak tension, decreased rate of tension development, increased total twitch duration, decreased Ca^{++} flux, and decreased cyclic AMP formation and activity (11). The chronotropic effect of catecholamines is due to increased deactivation of outward K^+ currents which increases the rate of diastolic depolarization of pacemaker cells (11).

A decrease in sympathetic tone is indicated by the results obtained. Sympathetic control is important in maintaining blood pressure, heart rate and myocardial contractility. The anesthetized animal tends to use sympathetic means to restore blood pressure levels (23). That the heart rate did not increase with a decrease in systemic pressure (Fig. 1), indicates that the baroreceptor reflex was unable to function suggesting impaired sympathetic activity. Sympathetic stimulation also is important in maintaining vasoconstriction; a decrease in sympathetic tone would decrease vascular resistance, thus lowering systemic pressure.

Another alternate hypothesis involves vagal stimulation. Increased vagal activity would explain the decreased heart rate and the failure of the sympathetics to check vagal action. To elucidate the action AG has on the sympathetics and vagus, studies should be performed on sympathectomized (reserpine or 6-hydroxydopamine) and vagotomized animals.

Premature ventricular systoles, evidenced in both Methoxyflurane and AG-Methoxyflurane animals (Fig. 2) are the result of enhanced pacemaker activity at ectopic foci. No P wave was observed, indicating an ectopic focus not in the atria. The intraventricular septum is susceptible to induced ectopic foci formation due to mechanical stimulation. This suggests that the premature ventricular systoles present in cannulated animals could be due to the cannula stimulating the septum.

Acknowledgments

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Ectoparasites of squirrels of the genus *Sciurus* from Indiana

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Abstract

The ectoparasites of *Sciurus niger* and *S. carolinensis* from Indiana were studied using visual observation and a potassium hydroxide hair-dissolving technique. Sucking lice were most abundant with three species found on each species of squirrel; *Enderleinellus longiceps*, *Neohaematopinus sciurinus* and *Hoplopleura sciuricola* on *S. niger* and *E. longiceps*, *N. sciuri* and *H. sciuricola* on *S. carolinensis*. *Hoplopleura sciuricola* is reported from gray squirrels for the first time. One flea, *Orchopceus howardi*, was predominant on both species of squirrel. Three species of ticks, *Amblyomma americanum*, *Dermacentor variabilis* and *Ixodes marxi*, were found on both species of squirrel, with *I. marxi* being reported from *S. niger* for the first time. About eight species of chiggers were found, none in great numbers. *Trombicula fitchi* and *Walchia americana* were most abundant. A hypopial mite, *Echimyopus nyctomys*, is reported from Sciuridae in the United States for the first time. Warble larvae, *Cuterebra* sp., were found in small numbers on both species of squirrels.

Introduction

There are relatively few records of ectoparasites of squirrels of the genus *Sciurus* from Indiana. Wilson (10) accumulated much information on ticks, sucking lice and fleas resulting from examination of 194 collections from gray squirrels and their nests, and from 47 fox squirrels. Other than this there are only scattered records. The purpose of this paper is to present information on ectoparasites and other associates found in the fur of the Fox Squirrel, *Sciurus niger*, and the Gray Squirrel, *S. carolinensis*, from Indiana.

Materials and Methods

Squirrels for this study were collected from several counties in Indiana, including a number from Vigo, Clay, Parke, Jackson and Martin counties. Many were collected during squirrel season (August through October) although a number were collected as roadkills.

Two main methods were used in collecting ectoparasites. Actual counts were made, except when large numbers of some species were present, then estimates were made. The fur of many of the squirrels was examined visually with the aid of a 10 to 70 power zoom dissecting microscope. All parts of the body were examined by lifting the hairs with dissecting needles. Special effort was made to find parasites on the rump, nape, around the bases of the legs, on the top of the head and around the ears. The second method was by dissolving the fur in potassium hydroxide as follows (see 3): The complete skin of each squirrel was placed in individual containers with about 500 ml of 5 percent KOH. After 24 hours all remaining fur was scraped from the

skin with a metal spatula. The KOH and dissolved fur was heated 1 to 4 hours on a hot plate at about 95°C under a hood. The mixture was allowed to settle overnight. Excess KOH was decanted and the remaining mixture of KOH, dissolved fur and ectoparasites was centrifuged for 5 minutes at about 1200 rpm. Again excess KOH was decanted and zinc sulfate solution was added to almost fill the centrifuge tubes. The tubes were agitated until the pellet at the bottom was completely broken up, and again centrifuged. The solution and parasites were decanted into petri dishes which were then examined with the dissecting microscope.

Fresh squirrels were examined visually after interfollicular mites were discovered by dissolving the fur. Hairs on the tail and around the anus were pulled and their follicles squeezed with microforceps.

During the early part of the study, all individuals were examined by visual observation; later all squirrels were dissolved, thus we have some comparison between the two methods.

Results and Discussion

Sucking lice were the most abundant forms found (Table 1), with three species on *Sciurus niger*, *Enderleinellus longiceps*, *Neohaematopinus sciurinus*, and *Hoplopleura sciuricola*, and three species on *S. carolinensis*, *E. longiceps*, *N. sciuri* and *H. sciuricola*, listed in order of decreasing abundance. Thus one species of *Enderleinellus* and one of *Hoplopleura* is found on both species of squirrels while different species of *Neohaematopinus* are found on the two. Wilson (10) found 1028 individuals of *N. sciuri* and 135 of *E. longiceps* on gray squirrels and 83 individuals of *E. longiceps*, 35 of *N. sciurinus* and 19 of *H. sciuricola* on *S. niger*. Thus the three species of lice on *S. niger* are in the same order of decreasing abundance on *S. niger* as indicated by both studies. But, on gray squirrels, the order of *E. longiceps* and *N. sciuri* is switched and *H. sciuricola* is added.

Essentially one flea, *Orchopeas howardi*, was found on both species of squirrels, however, one specimen of *O. leucopus*, likely accidental, was found on *S. niger*. Wilson (10) reported 1032 individuals of *O. howardi* on *S. carolinensis* and 108 on *S. niger*, as the only important flea of both species. In addition he found one individual of *Ctenocephalides felis*, and one of *Conorhinopsylla stanfordi* on *S. carolinensis* and one of *O. leucopus* on *S. niger*. Whitaker and Corthum (8) reported *O. howardi* from *S. niger* from Vigo County, but those data are incorporated in this paper.

Three species of ticks were found on both gray and fox squirrels, *Amblyomma americanum*, *Dermacentor variabilis* and *Ixodes marxi*. Wilson (10) found 17 individuals of *I. marxi* on *Sciurus carolinensis* and 22 individuals of *D. variabilis* on *S. niger*, but no individuals of *A. americanum* on either. It will be noted that a rather large number of individuals of *Amblyomma* were reported during the present study. However, all of those from *S. niger* are from squirrels from The Crane Naval Depot, in Martin County, while those from the Gray Squirrel were all from German Ridge, Perry County. Wilson (10) summarizes

the literature on this species, and found that it is primarily southeastern in the United States, occurring north sparingly to include only the southern tips of Indiana, Illinois and Ohio. Wilson (10) found it three times during his studies, on the wood thrush, man and the dog, from Brown, Tippecanoe and Harrison counties, respectively. However, the first two records could have entered the state via the host, while the latter appears to be native to Indiana. Wilson (10) expressed the opinion that *A. americanum* is a permanent, but rare resident in the southernmost counties of Indiana. That this species is apparently found mostly on *Sciurus* in southern Indiana, but is absent on squirrels we have taken over most of the rest of the state, seems to support Wilson's opinion.

About eight species of chiggers were taken, none of them in large numbers. Only *Trombicula fitchi* and *Walchia americana* occurred with any degree of regularity. However, except for *Eutrombicula alfreddugesi* and *Neotrombicula whartoni*, none of the chiggers had been previously reported from Indiana. Chiggers obtained using the hair dissolving technique were mostly in poor shape with 40 specimens being unidentifiable.

Other than chiggers, the only abundant mite on both species of squirrels was *Echimyopus nyctomys* which was taken using the dissolving technique. Fain (2) described *E. nyctomys* from hair follicles of the venter and dorsum of Sumichrast's Vesper Rat, *Nyctomys sumichrasti* (Cricetidae), from Guatemala. Our specimens may represent a new subspecies (A. Fain, pers. comm.). Individuals of *E. nyctomys* taken by hair dissolving were mascerated and not suitable for identification. Once their presence was known, a series of mites was taken from both species of squirrels by pulling hairs and squeezing hair follicles of the tail and around the anus. *Haemogamasus reidi* and *Androlaelaps casalis* are species commonly found on squirrels of the genus *Sciurus*, while *A. fahrenheitzi* is one of the least host specific North American mites (9). Other mites reported on *S. carolinensis* in North America previously, but not during the present study are *Cheyletus eruditus* (1), and perhaps *Haemogamasus ambulans* (5, 6, 7, but see 9, p. 2), and *Laelaps nuttalli* (11). The only mite previously reported from *S. niger* but not taken during this study was *Eulaelaps stabularis*, taken by Morlan (4).

Two warble larvae, *Cuterebra* sp., were found in the abdominal area of one Fox Squirrel and one in the dorsum of the neck in a Gray Squirrel.

Because of the poor condition of specimens obtained, dissolving is recommended only for determining the presence of skin and hair-follicle mites. Visual searches should then be made of additional hosts to obtain identifiable specimens. In addition, hair dissolving is time consuming and KOH fumes can cause respiratory problems. Another problem with dissolving is that many specimens are lost due to chunks of sediment being caught between setae or legs thus keeping them from floating in the zinc sulfate solution.

TABLE 1. Ectoparasites of 137 fox squirrels, *Sciurus niger*, and 47 gray squirrels, *S. carolinensis*, examined by observation of fur and by dissolving the fur in KOH. Values are given as percent of hosts infested and average number of parasites per host. Numbers of hosts, hosts infested and number of parasites are in parentheses.

	Fox squirrels				Gray squirrels			
	Visual (104)		Dissolving (33)		Visual (24)		Dissolving (23)	
	% with par.	Av. # par./host	% with par.	Av. # par./host	% with par.	Av. # par./host	% with par.	Av. # par./host
<i>Anoplura</i> (Sucking lice)								
<i>Enderleinellus longiceps</i>	45.2 (47)	14.25 (1482)	57.6 (19)	33.21 (1096)	63.5 (15)	18.17 (436)	69.6 (16)	25.30 (582)
<i>Neohaematopinus sciurinus</i>	28.9 (30)	7.95 (827)	60.6 (20)	11.67 (385)	—	—	—	—
<i>Hoplopleura sciuricola</i>	20.2 (21)	4.7 (489)	12.1 (4)	0.39 (13)	4.2 (1)	0.04 (1)	13.0 (3)	1.57 (36)
<i>Neohaematopinus sciuri</i>	—	—	—	—	62.5 (15)	24.63 (591)	60.9 (14)	16.39 (377)
<i>Siphonaptera</i> (Fleas)								
<i>Orchopeas howardi</i>	38.5 (40)	1.77 (184)	21.2 (7)	0.42 (14)	54.2 (13)	0.92 (22)	52.2 (12)	1.30 (30)
<i>Orchopeas leucopus</i>	1.0 (1)	0.02 (2)	—	—	—	—	—	—
<i>Ixodidae</i> (Ticks, Acari)								
<i>Amblyomma americanum</i>	6.7 (7)	0.44 (46)	—	—	12.5 (3)	2.38 (57)	—	—
<i>Dermacentor variabilis</i>	8.7 (9)	0.14 (15)	—	—	16.7 (4)	0.33 (8)	4.4 (1)	0.04 (1)
<i>Ixodes marxi</i>	—	—	15.2 (5)	0.46 (15)	8.3 (2)	0.17 (4)	13.0 (3)	0.13 (3)

Trombiculidae (Chiggers, Acari)

<i>Trombicula fitchi</i>	6.7 (7)	0.31 (32)	24.2 (8)	0.46 (15)	4.2 (1)	0.17 (4)	30.4 (7)	0.39 (9)
<i>Walchia americana</i>	4.8 (5)	0.19 (20)	9.1 (3)	1.36 (45)	8.3 (2)	0.17 (4)	17.4 (4)	0.39 (9)
<i>Neotrombicula sylviagi</i>	1.0 (1)	0.05 (5)	—	—	—	—	—	—
<i>Migmatrombicula cynos</i>	1.9 (2)	0.02 (2)	—	—	—	—	—	—
<i>Neotrombicula whartoni</i>	—	—	27.3 (9)	2.06 (68)	—	—	13.0 (3)	0.44 (10)
<i>Eutrombicula alfreddugesi</i>	—	—	9.1 (3)	0.12 (4)	4.2 (1)	0.04 (1)	13.0 (3)	0.13 (3)
<i>Leptotrombidium</i> sp.	—	—	6.1 (2)	0.12 (4)	—	—	13.0 (3)	0.61 (14)
<i>Microtrombicula trisetica</i>	—	—	—	—	4.2 (1)	0.04 (1)	—	—
Other mites (Acari)								
<i>Haemogamasus reidi</i>	4.8 (5)	0.11 (11)	6.1 (2)	0.24 (8)	8.3 (2)	0.42 (10)	26.1 (6)	1.04 (24)
<i>Androlaelaps casalis</i>	3.9 (4)	0.09 (9)	12.1 (4)	1.42 (47)	8.3 (2)	0.67 (16)	17.4 (4)	1.91 (44)
<i>Androlaelaps fahrenheitzi</i>	1.9 (2)	0.04 (4)	6.1 (2)	0.09 (3)	4.2 (1)	0.04 (1)	4.4 (1)	0.04 (1)
<i>Dermacarus</i> sp.	1.0 (1)	0.02 (2)	—	—	—	—	—	—
<i>Echinogonypus nyctomys</i>	—	—	33.3 (11)	10.36 (342)	—	—	21.7 (5)	2.22 (51)
<i>Macrocheles</i> sp.	—	—	—	—	—	—	4.4 (1)	0.04 (1)
Diptera								
<i>Cuterebra</i> sp.	1.0 (1)	0.02 (2)	—	—	—	—	4.4 (1)	0.04 (1)

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The Respiratory Effects of Prostaglandin F_{2α} in Anesthetized Cats

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Abstract

Prostaglandin F_{2α} was administered to eight anesthetized cats. The respiratory response to the prostaglandin was assessed by mass spectrometric analysis of expired respiratory gases, pulmonary resistance monitoring and systemic blood pressure determination. Prostaglandin F_{2α} was found to elicit significant decreases in fractional expired carbon dioxide, alveolar carbon dioxide tension, VA/VT, alveolar ventilation, minute alveolar ventilation, tidal volume, oxygen consumption, carbon dioxide production, systemic blood pressure and heart rate. Significant increases were found in fractional expired oxygen, alveolar oxygen tension and pulmonary resistance. The effects of prostaglandin F_{2α} diminished within 10 min after administration.

Introduction

Various prostaglandins have been shown to affect respiration in anesthetized animals. Prostaglandin E₁ has been shown to increase respiratory rates in anesthetized dogs (5). Alveolar ventilation in anesthetized dogs was reportedly increased by administration of prostaglandin E₂ or prostaglandin A₁ (9). Administration of prostaglandin F_{2α} (PGF_{2α}) to anesthetized dogs caused decreased alveolar ventilation (11) while PGF_{2α} has been reported to cause an increase in respiratory frequency in anesthetized cats (8). In other studies with anesthetized cats, PGF_{2α} was found to increase bronchial resistance while decreasing systemic blood pressure (2).

With the increasing interest in the respiratory role of PGF_{2α}, we initiated studies to determine respiratory function values in anesthetized cats treated with PGF_{2α}. Parameters were measured by means of mass spectrometric respiratory gas analysis and pulmonary resistance calculation.

Materials and Methods

Eight cats of both sexes weighing between 2.2 kg and 6.0 kg were anesthetized by intraperitoneal injection of sodium pentobarbital (30 mg/kg) and tracheostomized. An L-shaped metal tracheal cannula was inserted and secured with sutures. An inlet/exhaust valve arrangement permitted the inhalation of ambient fresh air while routing the expired air to a mixing chamber. A sampling cannula (polyethylene tubing 1.22 mm o.d.) from the respiratory gas analysis apparatus was positioned in the tracheal cannula. A second sampling cannula was placed in the expired air mixing chamber.

To determine respiratory flow rate, tidal volume and transpulmonary pressure, a Fleisch Number 00 Pneumotachograph was inserted between the tracheal cannula and the inlet/exhaust valve system and connected to a Statham PM-5 pressure transducer. Transpulmonary pressure was determined by inserting a Reisch Number 20

cannula through the animal's chest wall at the seventh intercostal space and positioning one end of the cannula in the intrapleural cavity. The other end of the cannula was connected to a second PM-5 pressure transducer. A sidearm connection between the tracheal cannula and the second pressure transducer completed the system for determining transpulmonary pressure.

Signals from the flow rate pressure transducer were amplified and integrated to yield tidal volume values by a Beckman Type R Dynograph. The transpulmonary pressure transducer was also connected to the dynograph. Pulmonary resistance was calculated using the method of Amdur and Mead (1).

Analyses of respiratory gases were made with a Medspect MS-8 mass medical spectrometer (Scientific Research Instruments Corporation, Baltimore, MD). The spectrometer utilizes the tracheal-positioned sampling cannula to sample end-expired oxygen and carbon dioxide. The second cannula (positioned in the expired air mixing chamber) permitted determination of mean mixed-expired oxygen and carbon dioxide levels. Signals from the spectrometer were also recorded on the Dynograph. This allowed each gas analysis to be graphically recorded on an individual channel.

Arterial blood pressure was determined by cannulation of a femoral artery with saline-filled polyethylene tubing connected to a Statham P23AA pressure transducer and recorded on the Dynograph. Heart rate was determined by counting pulse deflections in the blood pressure tracing.

The cephalic vein was catheterized for drug administration. The drug dosage was dissolved in 1 cc of physiological saline and injected over a 30 sec period, followed by a rapid flushing of the cannula with 1 cc of saline.

Prostaglandin F_{2α} (20 μg/kg) was injected into the animals no sooner than 30 min after the completion of surgical preparation. Measurements of end-expired oxygen, end-expired carbon dioxide, mean mixed-expired oxygen, mean mixed-expired carbon dioxide, respiratory flow rate, tidal volume and transpulmonary pressure were made before and at 1, 3, 5, 10, 15 and 30 min past the end of PGF_{2α} injection.

Calculations

The following formulas were utilized in determining the various functional respiratory parameters. Symbols and gas equations conform to Comroe et al (3).

PB Atmospheric pressure (mm Hg)

PB02 Partial pressure of oxygen in ambient air (mm Hg)

PBN2 Partial pressure of nitrogen in ambient air (mm Hg)

MEPO2 Mean mixed-expired oxygen (mm Hg)

MEPCO2 Mean mixed-expired carbon dioxide (mm Hg)

AAO2 End-expired oxygen (mm Hg)

AACO2 End-expired carbon dioxide (mm Hg)

VT Per breath tidal volume

f Respiratory rate per min

vr Tidal volume flow rate (cc/sec)

TPP Transpulmonary pressure (cm H₂O/l/sec)

PBC PB corrected for water vapor pressure

Fractional inspired nitrogen (FIN₂):

$$\frac{PBN_2}{PB}$$

Fractional inspired oxygen (FIO₂):

$$\frac{PBO_2}{PB}$$

Fractional expired oxygen (FEO₂):

$$\frac{PBC(MEPO_2)}{PB}$$

Fractional expired carbon dioxide (FECO₂):

$$\frac{PBC(MEPCO_2)}{PB}$$

Alveolar oxygen tension in mm Hg (PALVO₂):

$$\frac{[FIO_2 (PBC) - PALVCO_2] [FIO_2 + 1 - FIO_2]}{R}$$

Alveolar carbon dioxide tension in mm Hg (PALVCO₂):

$$PBC(AACO_2)$$

Oxygen consumption cc per breath (VO₂):

$$VT - \frac{[FIO_2(1 - FECO_2) - FEO_2]}{(1 - FIO_2)}$$

Carbon dioxide production cc per breath (VCO₂):

$$VT - \frac{FECO_2(1 - FIO_2)}{(1 - FIO_2)}$$

Respiratory quotient (R):

$$\frac{VCO_2}{VO_2}$$

Per breath alveolar ventilation in cc (VA):

$$PBC - \frac{R}{PACO_2} - VT$$

Percent alveolar ventilation (VA/VT):

$$VA/VT$$

Minute alveolar ventilation in cc (VA):

$$f(VA)$$

Pulmonary resistance cm H₂O/l/sec

$$\frac{TPP}{vr}$$

Results

Respiratory function values obtained before and after PGF_{2a} administration are summarized in Table 1. After one minute (following the end of drug injection) significant decreases were noted in fractional expired carbon dioxide, alveolar carbon dioxide tension, VA/VT, alveolar ventilation, minute alveolar ventilation, tidal volume, oxygen consumption, carbon dioxide production, systemic blood pressure, and heart rate. These decreases were observed to remain constant through the ten minute post injection point. Gradual return of the respiratory parameters toward the pre-injection levels occurred between the 10 min and 30 min post injection points. Similarly, the fractional expired oxygen, alveolar oxygen tension and pulmonary resistance were seen to increase significantly at the one minute post injection point and remain elevated to the ten minute post injection point. After ten minutes these values began to decrease toward control levels. Respiratory rate and respiratory quotient values did not change significantly following PGF_{2a} administration.

Discussion

Other workers have reported that administration of PGF_{2a} to anesthetized animals precipitates respiratory impairment. The respiratory dysfunction was characterized by an increase of airways resistance, a decrease in alveolar ventilation, and a drop in systemic blood pressure (9, 11).

The respiratory and blood pressure effects of PGF_{2a} have been linked to the substance's action on smooth muscle. Bronchoconstriction results from bronchial smooth muscle contraction. Response of vascular smooth muscle is specific to the location of the vessel and can result in either constriction or dilation. The effects of PGF_{2a} on smooth muscle are thought to be direct and without neuronal mediation (4).

Although the exact mechanism of action of PGF_{2a} at the cellular level is not known, a great deal of data indicate that the effects are the result of an influence on cellular cyclic AMP. Depending on the tissue in question PGF_{2a} can either increase or decrease the cyclic AMP level (4).

The data derived from our study would indicate that PGF_{2a} acts as a bronchoconstricting agent eliciting a generalized contraction of the bronchial smooth muscle. The reduction of airway caliber is accompanied by a reduction of tidal volume with a concomitant decrease in both VA/VT and alveolar ventilation. The reduction in minute alveolar ventilation is due to reduced per breath alveolar ventilation, since respiration rate was unaltered. Additionally, the measurements of alveolar gas exchange (fractional expired oxygen, fractional expired carbon dioxide, alveolar oxygen tension, and alveolar carbon dioxide tension) suggest a reduction in the number of alveoli being ventilated. This reduction in total alveolar surface results in an overventilation of those alveoli with patent airways. With a decreased alveolar air demand (a lessened number of functional alveoli as a consequence of constricted airways) the composition of expired and alveolar air is found to be altered. Less oxygen is being extracted from inspired air and less

TABLE 1. *The effects of Prostaglandin F_{2a} in anesthetized cats.*^a

Control	1 min	3 min	5 min	10 min	15 min	30 min
FE _{O₂}	0.170±0.003	0.181±0.004	0.179±0.004*	0.174±0.006	0.175±0.006*	0.174±0.003
FE _{CO₂}	0.034±0.002	0.022±0.005*	0.026±0.005*	0.028±0.006	0.030±0.005	0.032±0.003*
PAO ₂	116.9±3.0	125.2±6.2*	139.3±15.3*	117.1±7.3	121.5±4.5	120.4±2.3*
PACO ₂	33.0±2.3	26.8±5.7*	29.1±4.5*	31.2±3.6	31.1±3.9	32.3±3.8
VA/VT	77.8±1.7	70.1±2.4*	67.2±4.2*	67.7±5.1*	72.6±4.1	74.6±2.0
Alv Vent	30.6±1.9	19.5±2.7**	21.7±1.5*	21.3±2.1**	24.1±2.3*	26.6±1.9*
Min Vent	690±82.6	475±63.0*	448±32.5*	458±56.2*	540±85.9*	640±88.6
Tidal Vol	39.1±1.9	26.3±2.9**	30.3±2.2*	31.3±1.6*	33.0±2.1*	35.5±2.1*
Resistance	4.44±0.57	9.78±1.62*	7.77±1.32*	7.35±1.26*	7.59±1.32*	6.78±1.11*
Resp Rate	22±2	22±2	22±2	22±1	22±2	24±2
Blood Press	146±5.0	124±3.9*	131±4.2*	136±4.0*	140±4.2*	141±5.3*
Heart Rate	216±10.2	148±7.2*	165±4.0**	193±10.8**	202±11.7*	208±10.8*
Resp Quot	0.80±0.06	0.96±0.08	0.92±0.08	0.91±0.09	0.95±0.10	0.92±0.10
O ₂ Consump	2.31±0.19	1.14±0.23**	1.26±0.26**	1.62±0.27*	1.53±0.29*	1.77±0.28*
CO ₂ Product	1.86±0.17	1.08±0.17**	1.17±0.17*	1.47±0.29*	1.44±0.22**	1.62±0.17*

^aData expressed as the means of eight determinations. Readings are shown ± S.E.; significance calculated by paired t-test. Levels of significance are expressed by the following: *p<0.05 and **p<0.01.

carbon dioxide is being released into exhaled air so that the oxygen component of expired air is increased. Similarly, the oxygen tension of the ventilated alveoli is found to be increased due to the nearly maximal ventilation of the remaining open alveoli while the alveolar carbon dioxide tension is reduced.

With the presumed reduction of total oxygen absorbing (and carbon dioxide liberating) alveolar surface, the oxygen consumption and carbon dioxide production of the animals dropped significantly. The decreases in both parameters were proportional so that no resulting significant change was noted in the respiratory quotient.

The deleterious pulmonary actions induced by the administration of PGF₂ α were accompanied by a precipitous drop in systemic blood pressure and bradycardia. These reductions remained throughout the length of the post drug observation time. Two possible mechanisms operating singularly or in combination may be responsible for the observed cardiovascular effects.

Injection of PGF₂ α in anesthetized dogs has been shown to increase pulmonary arterial pressure (6). Similarly an increase in right ventricular pressure was noted in anesthetized cats upon PGF₂ α administration (2). With the description of lobar artery contraction in anesthetized dogs subjected to PGF₂ α administration (6), it would appear that the congestion resulting from constriction of the pulmonary arteries would precipitate a systemic blood pressure drop and heart rate decline.

A second possible mechanism for the systemic blood pressure reduction involves peripheral vasodilation. A report states that PGF₂ α has shown vasodilator qualities in specific instances (2). With extensive vasodilation a fall in systemic blood pressure of the magnitude observed could occur.

Conclusion

Based on the data derived from respiratory gas analysis and pulmonary resistance calculation, it would appear that PGF₂ α acts as a bronchoconstricting agent. Administration of PGF₂ α induced within one minute significant bronchoconstriction in the anesthetized cat. Accompanying the bronchoconstriction was a significant depression in systemic blood pressure and bradycardia. These reactions to PGF₂ α began to gradually diminish 10 min after prostaglandin administration.

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Effect of Saline and Saline Deprivation on Adrenal Regeneration Hypertension

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Abstract

Chronic increased ingestion of sodium chloride speeds up the rate of hypertension development caused by unilateral adrenalectomy and contralateral adrenal enucleation. Also, sodium retention is possibly a factor in the pathogenesis of adrenal Regeneration Hypertension (ARH). The present studies were undertaken to test the hypothesis that acute deprivation of excessive sodium intake leads to decreased sodium retention during the initiating period of ARH and thus alleviates or delays the onset of the disease. Sixty female weanling rats were adrenalectomized on the right side and adrenal enucleated on the left side, and were divided into five groups of 12 animals per group. Group 1 was given 1% NaCl to drink, group 2 was allowed tap water for 24 hours and then placed on saline, group 3 was allowed tap water for 48 hours and then placed on saline, group 4 drank water for 72 hours and then was given saline, group 5 was given tap water. The rats were individually housed and body weights and blood pressures taken at 3, 5, and 7 weeks post surgery. They were sacrificed at 7 weeks and weights taken of the hearts and kidneys. At 7 weeks the mean systolic blood pressure in mm Hg was as follows for the successive groups as given above: 190, 163, 134, 165, 140. The percentage hypertensive (>149 mm Hg) in each successive group was: 84, 75, 20, 66, 27. Such results indicate that continuous drinking of saline results in the severest form of hypertension in the greatest number of animals. Drinking only water, results in a drop in the incidence of hypertension but the animals that became hypertensive had extremely high blood pressures. Reducing the intake of salt during the first three days reduced the incidence and severity of hypertension but did not prevent its development in about 50% of the animals. Therefore, acute removal of excessive saline does not stop, but does alleviate somewhat, the early pathogenic processes in the development of adrenal regeneration hypertension. (Aided by a grant from the Eagles' Max Baer Heart Fund).

Introduction

Adrenal Regeneration Hypertension (ARH) is produced in young rats by unilateral adrenalectomy, contralateral adrenal enucleation and feeding 1% NaCl as drinking fluid (1). Studies by Skelton (3) indicate that unilateral kidney removal and elevated sodium intake are essential to the development of ARH. However, Hall et al. (4) reported that most rats on a normal stock diet ultimately develop hypertension, after appropriate operative procedures, even if tap or distilled water is used as the drinking fluid. The importance of sodium in aggravating or inducing hypertension is generally accepted. So, when Gaunt et al. (2) reported that sodium retention occurs after adrenal enucleation the logical conjecture was made that such a phenomenon could be important in the etiology of adrenal-regeneration hypertension. Since NA retention expands the extracellular fluid volume and increases the work load on the cardiovascular and excretory systems, it was deemed advisable to study the effects of acutely reducing this load by depriving the rats of saline immediately after operative procedures and at a time when the animals were undergoing severe traumatic stress as well as changes in water and electrolyte balance.

Thus, a series of experiments were conducted on rats deprived of saline for 24, 48, and 72 hours immediately after operation in hopes that such procedures would prevent or alleviate initial pathogenic processes brought about by excessive sodium retention. Results of these experiments are reported here.

Methods and Materials

Sixty female Charles River rats, 23 ± 1 day old, were used to study the effects of salt deprivation on the development of Adrenal Regeneration Hypertension. Using ether anesthesia, five groups of animals (12 per group) underwent right adrenonephrectomy and left adrenal enucleation. The enucleations were performed by making a small incision in the adrenal capsule and extruding the contents with forceps. Purina laboratory chow was given *ad libitum* and the rats were individually housed immediately post surgery. Group 1 was given 1% sodium chloride as drinking fluid continuously. Group 2 was allowed tap water for 24 hours and then placed on 1% saline. Group 3 was allowed tap water for 48 hours and then placed on 1% saline. Group 4 was allowed tap water for 72 hours and then placed on 1% saline. Group 5 remained on tap water throughout the experiment.

The arterial blood pressures were determined by the tail-cuff plethysmographic method in the unanesthetized rats at 3, 5, and 7 weeks following surgery. Blood pressures at or above 150 mm HG were considered hypertensive. After completion of blood pressure determinations at 7 weeks, the rats were sacrificed. The heart and kidney were removed, stored in formaldehyde, trimmed and weighed at a later date. Student's t-test was employed in arriving at statistically significant differences between paired means.

Results

The effect of salt deprivation on systolic arterial blood pressure and incidence of hypertension is shown in Table 1. Rats on continuous saline developed severe hypertension by the end of the five week period and this condition persisted until termination of the experiment at seven weeks. At this point, eighty-five percent of these animals were hypertensive.

Animals that were on tap water for twenty-four hours and then placed on 1% saline also exhibited marked hypertension at the end of five weeks with the mean being 187 mm Hg. Interestingly, at the end of seven weeks, their systolic arterial pressure had dropped to a mean of 163 but most (75%) of them were still hypertensive.

Rats maintained on tap water for 48 hours and then switched to 1% saline drinking fluid were mainly normotensive throughout the experiment with only 20 percent reaching the hypertensive level. At the end of the five week period, the blood pressures were spread over a large range with the mean being 137 mm Hg. At the end of seven weeks, a somewhat narrower range of values had developed with the mean being 134. One animal in this group died between the 5th and 7th week with a blood pressure of over 250 mm Hg.

TABLE 1. *The effects of salt deprivation on the systolic arterial blood pressures during development of adrenal regeneration hypertension.*

salt deprivation hours	3 weeks blood pressure mm/Hg	5 weeks blood pressure mm/Hg	7 weeks blood pressure mm/Hg	percent hypertensive
none	148 $\pm$ 8.1+	189 $\pm$ 7.7	190 $\pm$ 9.7	84
cont saline	(12)	(12)	(12)	
24	150 $\pm$ 5.1	187 $\pm$ 5.7	163 $\pm$ 6.2*	75
	(12)	(12)	(12)	
48	144 $\pm$ 7.2	137 $\pm$ 16.7*	134 $\pm$ 5.7*	20
	(11)	(11)	(10)	
72	151 $\pm$ 8.7	171 $\pm$ 9.1	165 $\pm$ 10.1	66
	(12)	(12)	(12)	
cont water	134 $\pm$ 8.1	166 $\pm$ 13	140 $\pm$ 4.1*	27
	(11)	(11)	(11)	

+ Entries are mean value $\pm$ standard error and number of cases.

* Denotes significant difference ($P < .05$) between the continuous saline controls and the deprived animals.

Hypertensive equals a systolic blood pressure >149 mm/Hg.

Rats maintained on tap water for 72 hours then switched to 1% saline drinking fluid exhibited hypertension at the end of both 5 and 7 weeks with the mean being 171 and 165 respectively. Here again, a slight fall in the pressures is noted between the 5th and 7th week, but it is not as pronounced as in group 2 (24 hour salt deprivation). In the 72 hour experiment, 66% of the animals were hypertensive at the end of 7 weeks.

The animals on continuous water exhibited the recurring odd characteristic of a drop in blood pressure between the 5th and 7th weeks. At the end of five weeks, the animals exhibited blood pressure rises of varying degrees; most remained normotensive, while a few of the animals developed severe hypertension. The mean at 5 weeks was 166. At seven weeks the mean was 140 with only 27% of the animals exhibiting hypertension.

The effects of salt deprivation on kidney, heart, and body weight are shown in Table 2. The body weights showed only one significant change, this being in group 2 (24 hour salt deprivation). The animals in this group exhibited a greater mean body weight than the control animals on continuous saline. This change is probably unimportant and the reason for the increase is unknown.

The kidney weights of the animals ingesting saline continuously and those deprived of saline for 24 and 72 hours, all showed marked increases over those given water continuously. The animals that were given saline after 48 hours (group 3) exhibited normal kidney weights and this correlated with their low blood pressures. Also, the mean kidney weight of animals given water continuously (group 5) was significantly lower than for saline fed controls. The heart weights showed the same pattern of change as the kidney weights. That is, those animals exhibiting hypertension had large hearts and kidneys, whereas those that were normotensive had smaller organ weights.

TABLE 2. *The effects of salt deprivation on the body weights, kidney, and heart weights at seven weeks after adrenal enucleation and unilateral nephrectomy.*

salt deprivation hours	kidney weights mg	heart weights mg	body weights g
none cont saline	2113.2 $\pm$ 95.0	846.5 $\pm$ 39.3	226 $\pm$ 13.2
24	2137.1 $\pm$ 69.3	886.4 $\pm$ 24.1	261 $\pm$ 7.5*
48	1691.4 $\pm$ 83.6*	685.4 $\pm$ 35.4*	225 $\pm$ 9.2
72	2034.8 $\pm$ 135.8	771.7 $\pm$ 45.0	230 $\pm$ 10.8
cont water	1492.9 $\pm$ 74.3*	710.0 $\pm$ 27.1*	246 $\pm$ 8.2

Entries are mean value $\pm$ standard error. Number of cases given in Table 1.

* Denotes significant difference ($P < .05$) between the continuous saline controls and the deprived animals.

Discussion

The results reported here confirm those of Hall et al. (4) who reported that adrenal-regeneration hypertension can be induced in sensitive animals without a high salt intake being imposed and that the hypertensive condition is aggravated by NaCl excess. Increased sodium chloride intake does not appear to be prerequisite for the pathogenic process to occur but extra sodium loads and accompanying body fluid expansion no doubt contribute to the severity and increase in incidence of the disease.

The report of sodium retention occurring soon after adrenal enucleation, and the suggestion that such retention may be a contributing factor in the early pathogenesis of adrenal regeneration hypertension (2) prompted us to test the hypothesis that acute deprivation of saline for 1 to 3 days immediately post-operatively might relieve the fluid and NaCl load placed on the cardiovascular system and kidneys and thus delay or alleviate the development of the hypertensive state. The results, while not striking, do indicate that short periods of salt deprivation immediately following operative procedures are helpful in reducing the severity and incidence of adrenal regeneration hypertension but do not prevent it from developing in about 50% of the animals. Again, such findings are consistent with those of others (4) who reported that replacement of saline drinking fluid with water at 2, 4, or 6 days post-operatively resulted in a mild form of hypertension development characterized by mean pressures approximating 152 mm Hg. Such values are in the same range as ours for rats deprived of saline for up to 72 hours.

In our studies group 2 (48 hour salt deprivation) deviated considerably from the expected and from the other salt deprivation groups. The mean blood pressure here was in the normotensive range but 2 rats of 10 were mildly hypertensive. Such findings by others are not uncommon. For instance, Rapp (5) reported a spontaneous decline in systolic arterial blood pressure in adrenal-regeneration hypertensive rats between 4 and 6 weeks post-operatively, and Hall et al. (4) reported unusually low blood pressures in one of his experimental groups and remissions of high pressure in sick animals. In our experiments, the seemingly aberrant group consisted of healthy rats and we have

no explanation as to why their blood pressures were lower than in the other groups deprived of salt for short periods of time.

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